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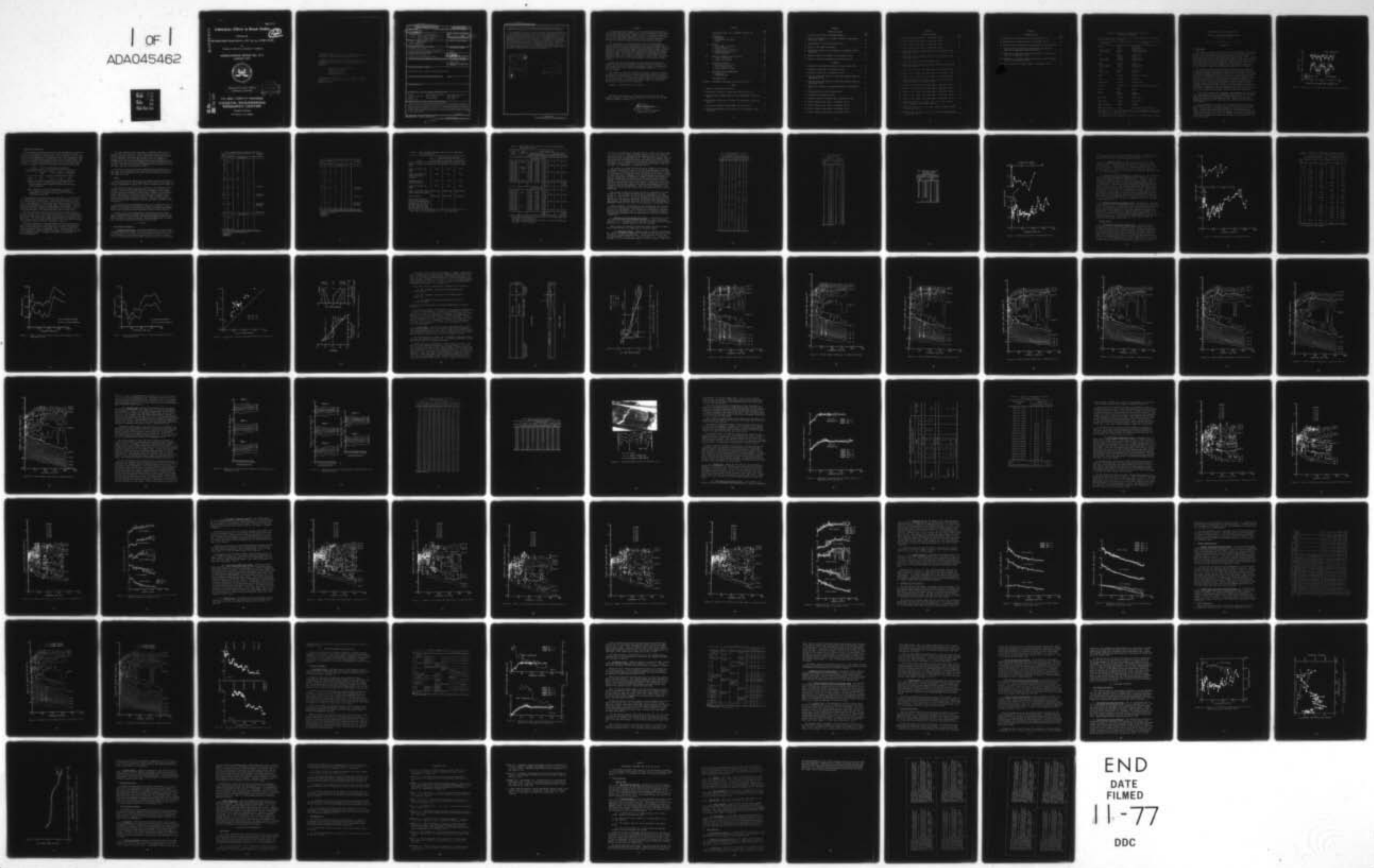

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Laboratory Effects in Beach Studies

Volume II

Movable-Bed Experiments with $H_o/L_o = 0.021$ (1970)

by

Charles B. Chesnutt and Robert P. Stafford

MISCELLANEOUS REPORT NO. 77-7
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two movable-bed experiments were conducted in 6- and 10-foot-wide wave tanks for 175 and 210 hours, respectively, with a wave period of 1.90 seconds and generated wave height of 0.36 foot. The reflection coefficient from the changing profile varied from 0.08 to 0.20 in the 6-foot tank and 0.04 to 0.19 in the 10-foot tank and the variations can be qualitatively related to changes in the profile shape.

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The profile in neither experiment attained an equilibrium shape, even though the shoreline position was stabilized by backshore renourishment.

For approximately the first 50 hours (or before the shoreline stabilization), the shoreline recession rate in the 6-foot tank increased from 0.06 to 0.14 foot per hour coincidently with a 10° Celsius temperature drop. The shoreline erosion rate in the 10-foot tank was 0.08 foot per hour, and the temperature was between 25° and 30° Celsius. The difference in recession rates between the two tanks is possibly due to differences in the distance from the generator to the initial shoreline (100 feet in the 6-foot tank and 61.7 feet in the 10-foot tank) or to temperature differences. Lateral variations occurred in the rate of development of the inshore zone in the 10-foot tank that did not occur in the 6-foot tank, indicating that the tank width may also have affected the profile development.

PREFACE

Ten experiments were conducted at the Coastal Engineering Research Center (CERC) from 1970 to 1972 as part of an investigation of the Laboratory Effects in Beach Studies (LEBS), to relate wave height variability to wave reflection from a movable-bed profile in a wave tank. The investigation also identified the effects of other laboratory constraints. The work was carried out under the CERC coastal processes program.

This report (Vol. II), the second of a series of eight volumes, analyzes two movable-bed experiments which show that wave height variability depends on a complex relationship between profile changes and wave reflection. The experiments suggest that tank width and length, and water temperature affect laboratory profile development and that under common laboratory conditions the profiles approach equilibrium more slowly than normally assumed. This study is aimed directly at the problems of the laboratory researcher or engineer in charge of a model study; ultimately, the results will be of use to field engineers in the analysis of model studies.

Volume I of this series documents the procedures used in the 10 movable-bed laboratory experiments, and also serves as a guide for conducting realistic coastal engineering laboratory studies. Volumes II to VII are data reports for the other experiments; Volume VIII is a final analysis report.

This report was prepared by Charles B. Chesnutt, principal investigator during the data analysis and report preparation phases of the work, and Robert P. Stafford, senior technician in charge of the two experiments. Dr. C.J. Galvin, Jr., Chief, Coastal Processes Branch, was the principal investigator during the planning and conduct of these two experiments and the early stages of the data reduction.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

LABORATORY EFFECTS IN BEACH STUDIES

Volume II. Movable-Bed Experiments with H_o/L_o = 0.021 (1970)

by
Charles B. Chesnutt and *Robert P. Stafford*

I. INTRODUCTION

1. Background.

Wave heights in movable-bed, coastal engineering laboratory experiments and models vary both in space and time (Fig. 1). Such variability is common over the constant depth section of wave tanks with movable beds (Savage, 1962; Fairchild, 1970a, 1970b; Galvin and Stafford, 1970). Because wave height enters many coastal engineering formulas to the second or third power, small variations in laboratory wave height can cause large errors when extrapolated to prototype conditions. Wave height variability is one of several laboratory effects, separate from scale effects, which can hinder attempts to solve coastal engineering problems in the laboratory.

The Laboratory Effects in Beach Studies (LEBS) project was initiated in 1966 to investigate the causes of variation in wave heights observed in longshore transport experiments in the Shore Processes Test Basin (SPTB) at the Coastal Engineering Research Center (CERC). Originally, wave height variability was thought to be caused by either resonance, generator malfunction, or inaccuracies in the wave gages. However, preliminary experiments indicated that wave reflection from the movable-bed profile and variation in the reflection as the profile adjusted to wave attack were the major causes of wave height variability. Since reflection occurs naturally when waves travel onto a beach, reflection cannot be eliminated. Therefore, the emphasis of the LEBS experiments has been to learn how reflection is affected by naturally occurring changes on the beach in order that coastal engineering laboratory studies can be better interpreted.

A total of 10 detailed LEBS experiments were conducted, and this report (Vol. II) discusses the first 2 experiments completed in 1970. The other eight experiments are discussed in five data reports (Vols. III to VII) as part of a series of eight reports on LEBS. Volume I of the series (Stafford and Chesnutt, 1977) discusses the contents and primary purposes of the reports.

The two experiments covered in this study have also been discussed in part in earlier reports. Chesnutt, et al. (1972) discussed the development of the profiles in four LEBS experiments, including the two in this study. Chesnutt and Galvin (1974) analyzed the relationship between reflection variability and profile development in the same four experiments discussed by Chesnutt, et al. (1972). Chesnutt (1975) analyzed other laboratory effects observed in three LEBS experiments, including one of the two in this volume.

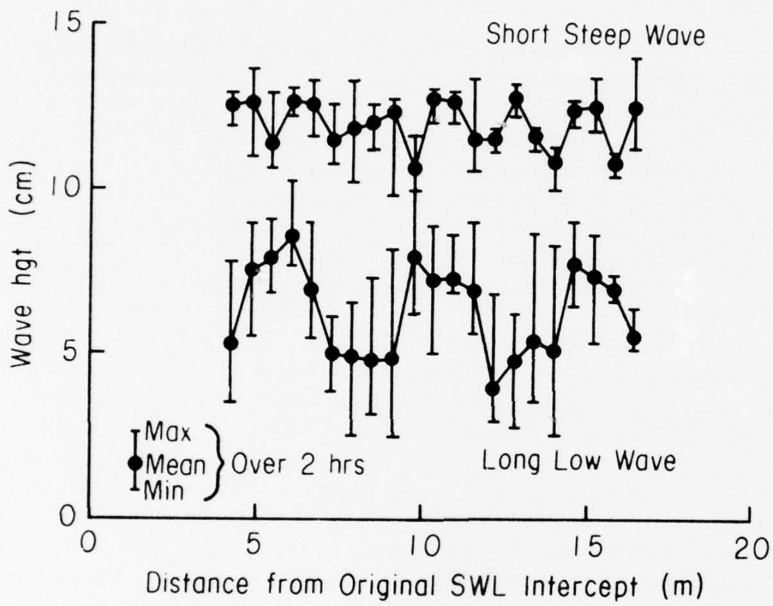

Figure 1. Examples of wave height variability in long, narrow tank.

2. Experimental Procedures.

The experimental procedures used in the LEBS experiments are described in Volume I (Stafford and Chesnutt, 1977) which provides the necessary details on the equipment, quality control, data collection, and data reduction for all 10 experiments. An appendix to this study documents the data collection and reduction procedures unique to these two experiments. The conditions of the two LEBS experiments (70X-06 and 70X-10) are summarized in Table 1. The table shows that the initial slope, water depth, wave period, wave height, and sand size were the same in the two experiments.

Table 1. Summary of experimental conditions.

Experiment[1]	Initial test length (ft)	Initial slope	Wave period (s)	Generated wave height (ft)
70X-06	100.0	0.10	1.90	0.36
70X-10	61.7	0.10	1.90	0.36

[1]Refer to Volume I (Stafford and Chesnutt, 1977) for relation between these experiments and the other eight LEBS experiments.

NOTE.--Constants for the two experiments: d_{50} (by dry sieve analysis) of quartz sand = 0.23 millimeter; water depth = 2.33 feet; wave energy flux = 5.8 foot-pounds per second-foot.

Two experimental facilities were used (see Figs. 3, 4, and 5 of Vol. I). Each facility consisted of two side-by-side wave tanks, one with a 0.10 concrete slope and the other a sand slope (also discussed in Sec. II, 2). The generator at the other end was common to both of the tanks so that each had identical wave energy input. The operation of the generators is described in Section IV and Appendix B of Volume I. The concrete slope provided a control (a bench-mark value) for the varying reflection measured in the neighboring tank with the movable bed.

The basic difference between the two facilities was the tank width. One pair of tanks, each 6 feet (1.8 meters) wide, was used for experiment 70X-06; the other pair, each 10 feet (3 meters) wide, was used for experiment 70X-10. The initial test length, from generator to stillwater level (SWL) intercept on the slope, was 100 and 61.7 feet (30.5 and 18.8 meters) in experiments 70X-06 and 70X-10, respectively (Table 1).

During the experiments, it became evident that the backshore length was too short, because the steady erosion of the sand slope caused the shore to reach the end wall of the tank after 54 hours in experiment 70X-06 and after 62 hours in experiment 70X-10. From then until the end of the experiments, sand was periodically added to the backshore to maintain an adequate supply. In effect, the erosion was stabilized by beach replenishment.

The initial grading of the sand slope in experiment 70X-10 was on 7 May 1970, the first run was on 14 May 1970, and the last run was on 30 November 1970 after 210 hours. Data collection was completed 2 December 1970. Experiment 70X-06 was begun 10 August 1970, was stopped on 5 December 1970 after 175 hours, and the data collection completed 15 December 1970. The dates are important because the experiments were run in outdoor facilities with water temperature varying with ambient air temperature. The major events of each experiment and the cumulative time at the end of each run are summarized in Table 2.

Table 3 gives the data collection schedule within each run for 1-, 2-, and 5-hour runs. During the first 2 hours when the runs were less than 1 hour long, the same data were collected, with the schedule depending on the length of the run.

3. Scope.

This report describes and analyzes the reduced data from LEBS experiments 70X-06 and 70X-10. The original data are available in an unpublished laboratory memorandum (Chesnutt, 1977) filed in the CERC library (CERTI-LI).

Wave reflection, profile surveys, sediment-size distribution, breaker characteristics, and water temperature are discussed in the following section. Section III discusses (a) profile development, which examines the interrelation of changes in profile shape, sediment-size distribution, breaker characteristics, and water temperature; and (b) profile reflectivity, which examines the interrelation of changes in profile shape, breaker characteristics, and wave reflection. Section IV discusses the results of wave height variability, profile equilibrium, and other laboratory effects.

The conclusions and recommendations (Sec. V) are aimed directly at the problems of the laboratory researcher or engineer in charge of a model study. Field engineers should be aware of these conclusions and recommendations when discussing and analyzing model studies of their projects.

The data in this study (particularly the profiles) may have other uses. The researcher can use these data, after consideration of the laboratory effects, to analyze short- and long-term changes in profile shape. After an analysis of the scale effects, the field engineer may use these data to determine generalized shoreline recession rates.

II. RESULTS

1. Wave Height Variability.

a. Incident Wave Heights. Wave height measurements from the continuous recording of water surface elevation along the center range at station +25 during the first 10 minutes of each experiment are shown in Table 4. The wave heights in the movable-bed tanks varied from 0.09 to 0.38 foot (2.7 to 11.6 centimeters) in experiment 70X-06, and from 0.15 to 0.43 foot

Table 2. Experimental schedule for experiments 70X-06 and 70X-10.

Cumulative time[1] (hr)	Date (1970)	Wave record No.	Survey No.	Special data collected
		Experiment 70X-06		
0:00			1	
0:10	10 Aug.	001	2	
0:25		002	3	
0:40		003	4	
1:00		004	5	
1:30		005	6	
2:00		006	7	
3:00		007	8	
-----[2]		--[2]	-----[2]	
------		---	------	
------		---	------	
9:00		013	14	
10:00	16 Sept.	014	15	
12:00		015	16	
-----[3]		--[2]	-----[2]	
------		---	------	
------		---	------	
50:00	16 Oct.	034	35	ripple photos
-----[3]		--[2]	-----[2]	
------		---	------	
------		---	------	
98:00		058	59	
100:00	9 Nov.	059	60, 61	profile survey; ripple photos
105:00		060	62	
-----[4]		--[2]	-----[2]	
------		---	------	
------		---	------	
150:00	23 Nov.	069	71, 72	profile survey; ripple photos; sand samples
-----[4]		--[2]	-----[2]	
------		---	------	
------		---	------	
175:00	5 Dec.	074	77	profile survey
		Experiment 70X-10		
0:00			1	
0:10	14 May	001	2	
0:25		002	3	
0:40		003	4	
1:00		004	5	
1:30		005	6	
2:00		006	7	
3:00		007	8	
-----[2]		--[2]	-----[2]	

[1]Wave records were taken during run ending at cumulative time shown; surveys, sand samples, and ripple photos were taken after the run ending at the cumulative time shown (see also Table 3).
[2]Increments of 1.
[3]Increments of 2.
[4]Increments of 5.

Table 2. Experimental schedule for experiments 70X-06 and 70X-10.--Continued

Cumulative time[1] (hr)	Date (1970)	Wave record No.	Survey No.	Special data collected
Experiment 70X-10				
------		---	------	
------		---	------	
9:00		013	14	
10:00	12 June	014	15	
12:00		015	16	
-----[3]		--[2]	-----[2]	
------		---	------	
------		---	------	
50:00	27 July	034	35	
-----[3]		--[2]	-----[2]	
------		---	------	
------		---	------	
98:00		058	59	
100:00	21 Sept.	059	60, 61	profile survey; ripple photos
105:00		060	62	
-----[4]		--[2]	-----[2]	
------		---	------	
------		---	------	
150:00	2 Nov.	069	71	ripple photos
-----[4]		--[2]	-----[2]	
------		---	------	
------		---	------	
200:00	18 Nov.	079	81, 82	profile survey; ripple photos; sand samples
205:00		080	83	
210:00	30 Nov.	081	84	

[1]Wave records were taken *during* run ending at cumulative time shown; surveys, sand samples, and ripple photos were taken after the run ending at the cumulative time shown (see also Table 3).
[2]Increments of 1.
[3]Increments of 2.
[4]Increments of 5.

Table 3. Data collection schedule within runs for experiments 70X-06 and 70X-10.

Event	Time within runs (hr:min)[1]		
	1-hr runs	2-hr runs	5-hr runs
Photo of foreshore before start	before start	before start	before start
Photos of breaker and runup	0:01	0:01	0:01
Photos of breaker and runup before wave envelope	0:19	0:59	3:59
Recording of wave envelope started	0:20	1:00	4:00
Photos of breaker and runup	0:59	1:59	4:59
Photo of foreshore after water surface had calmed	after stop	after stop	after stop
Profile survey	after stop	after stop	after stop
Water temperature data collected in morning and afternoon of each day of testing; however, there may have been more than one run during each day.			

[1]See Table 2 for distribution of 1-, 2-, and 5-hour runs.

Table 4. Wave heights during first 10 minutes for experiments 70X-06 and 70X-10.

Cumulative time (min:s)	Wave period (s)	Wave height (ft)					
		Movable-bed tank			Fixed-bed tank		
		(max)	(min)	(avg.)	(max)	(min)	(avg.)
Experiment 70X-06							
0:00-0:20[1]	1.893	0.384	0.092	0.302			
0:20-0:40		0.358	0.295	0.326			
0:40-1:00		0.341	0.311	0.327	0.349	0.310	0.333
1:40-2:00	1.894	0.364	0.328	0.348			
2:40-3:00	1.896	0.333	0.303	0.312			
3:40-4:00		0.344	0.320	0.333			
4:40-5:00	1.893	0.355	0.331	0.344	0.333	0.309	0.324
5:40-6:00		0.339	0.306	0.322			
6:40-7:00		0.334	0.296	0.312			
7:40-8:00		0.330	0.314	0.320			
8:40-9:00		0.318	0.297	0.307			
9:40-10:00	1.895	0.322	0.292	0.306	0.335	0.305	0.320
				avg. 0.323			avg. 0.326
Experiment 70X-10							
0:00-0:20[2]		0.390	0.154	0.332			
0:20-0:40	1.85	0.376	0.328	0.354			
0:40-1:00		0.373	0.341	0.355	0.394	0.349	0.366
1:40-2:00		0.395	0.366	0.378			
2:40-3:00		0.379	0.345	0.360			
3:40-4:00		0.411	0.378	0.396			
4:40-5:00		0.396	0.376	0.385	0.396	0.376	0.385
5:40-6:00		0.413	0.379	0.396			
6:40-7:00		0.420	0.378	0.404			
7:40-8:00	1.85	0.408	0.340	0.377			
8:40-9:00		0.427	0.372	0.394			
9:40-10:00		0.410	0.357	0.384	0.391	0.351	0.371
				avg. 0.383			avg. 0.374

[1]This group includes waves 2 to 11; wave 2 is the very small wave and wave 6 is the high wave.

[2]This group includes waves 2 to 11; wave 2 is the very small wave and wave 7 is the high wave.

(4.6 to 13.1 centimeters) in experiment 70X-10. Ignoring the first group of 10 waves, the wave heights differed within the first 10 minutes by as much as 0.07 foot (2.1 centimeters) in experiment 70X-06 and 0.10 foot (3.0 centimeters) in experiment 70X-10. This difference suggests that the reflection from the movable-bed profile was varying significantly during the initial run. As expected, the wave heights varied less in the fixed-bed tanks, varying 0.04 foot (1.2 centimeters) in experiment 70X-06 and 0.05 foot (1.5 centimeters) in experiment 70X-10.

The average wave height for each record was determined by averaging the average of the last 10 waves in the last 20-second interval for each 10 minutes. In experiment 70X-06, the average wave height was 0.32 foot (9.8 centimeters); in experiment 70X-10 the height was 0.38 foot. Neither of these values can be compared to the nominal generated wave height 0.36 foot (11 centimeters) as indicated in Volume I, because the position of the gage between nodes and antinodes of the reflected wave envelope is unknown. Since the waves were recorded at the same distance from the reflector, the difference in the wave heights is likely due to the difference in the initial test length as the result of secondary waves or re-reflection from the wave generator. There was little difference in the average wave heights between the movable- and fixed-bed tanks for either experiment.

The average incident wave heights from the two experiments are shown in Table 5. These heights were determined by averaging all the wave heights on a given envelope as part of the automated method for determining the K_R (see Vol. I). The values determined in the fixed-bed tanks indicate that the generator operation variation and measurement errors in both movable- and fixed-bed tanks were ±0.005 foot (±0.15 centimeter) in experiment 70X-06 and ±0.015 foot (±0.45 centimeter) in experiment 70X-10.

The wave height in the movable-bed tank in experiment 70X-06 varied from 0.32 to 0.38 foot and in experiment 70X-10 from 0.34 to 0.39 foot (10.4 to 11.9 centimeters). The variation not attributable to generator variation and measurement error is likely due to re-reflection from the wave generator superposing with the generated wave creating a different incident wave.

b. Reflection from the Movable-Bed Profile. In measuring the reflection coefficient from a wave envelope recorded by a slowly moving gage (see Vol. I), it is assumed that the reflection coefficient does not change during the 5 to 7 minutes required to make the recording.

Table 6 gives the reflection coefficient versus time data for experiments 70X-06 and 70X-10 as determined by the manual method.

(1) Experiment 70X-06. Figure 2 shows the reflection coefficient, K_R, versus time data for experiment 70X-06 for all time and for the first 10 hours at a larger horizontal scale. During the first 10 hours, the K_R varied between 0.20 and 0.08. At 10 to 25 hours, K_R remained fairly constant (0.14 to 0.16) and then dropped to 0.08 at 31 hours. From 33 to

Table 5. Incident wave height (ft) for experiments 70X-06 and 70X-10.

Time (hr)	Experiment 70X-06 Movable bed	Experiment 70X-06 Fixed bed	Experiment 70X-10 Movable bed	Experiment 70X-10 Fixed bed
0.5	0.37	0.37	----	----
0.8	----	----	0.38	0.38
0.8	----	----	0.39	0.38
1.8	0.38	0.36	0.38	0.37
1.8	----	----	0.38	0.37
4.3	----	0.37	0.37	----
4.3	0.35	0.37	0.37	0.37
9.3	----	----	0.36	0.35
9.3	0.34	0.36	0.36	----
19	----	----	0.37	0.36
19	0.32	0.37	0.37	0.36
27	0.35	0.37	----	----
27	0.35	0.37	----	----
29	----	----	0.34	0.35
29	----	----	0.34	0.35
39	----	0.39	0.35	0.35
39	0.34	0.37	0.35	0.35
49	0.33	0.37	----	----
49	0.33	0.37	----	----
51	----	----	0.36	0.36
51	----	----	0.36	0.36
53	0.33	0.37	----	----
53	0.33	0.37	----	----
59	0.33	0.37	0.37	0.35
59	0.33	0.37	0.37	0.35
65	----	----	0.37	0.35
65	----	----	0.36	0.35
69	0.35	0.37	----	----
69	0.35	0.37	----	----
77	----	----	0.36	0.35
77	----	----	0.36	0.35
79	0.34	0.37	----	----
79	0.33	0.37	----	----
89	0.35	0.36	0.38	0.35
89	0.35	0.36	0.37	0.35
99	0.36	0.37	0.36	0.36
99	----	0.36	0.36	0.35
124	0.34	0.37	0.37	0.36
124	0.34	0.36	0.38	0.36
149	----	----	0.38	0.36
149	----	----	0.37	0.35
169	----	----	0.36	0.36
169	----	----	0.36	0.35
174	0.34	0.37	0.38	0.36
174	----	----	0.38	0.36

Table 6. Reflection coefficients versus time data for experiments 70X-06 and 70X-10 (manual method).

Experiment 70X-06		Experiment 70X-10	
Cumulative time (hr)	K_R	Cumulative time (hr)	K_R
0.2	0.195	0.2	0.134
0.5	0.101	0.4	0.145
0.8	0.107	0.8	0.124
1.3	0.146	1.4	0.132
1.5	0.136	1.8	0.105
2.3	0.122	3.4	0.132
3.3	0.131	4.4	0.126
4.3	0.132	5.4	0.138
5.3	0.108	6.4	0.147
6.3	0.120	7.4	0.106
7.3	-----	8.8	0.158
8.3	0.084	9.4	0.129
9.3	0.124	11.2	0.144
11	0.154	13	0.115
13	0.139	15	0.117
15	0.136	17	0.108
17	0.144	19	0.115
19	0.164	21	0.070
21	0.150	23	0.062
23	0.158	25	0.077
25	0.150	27	0.095
27	0.113	29	0.068
29	-----	31	0.043
31	0.080	33	0.055
33	0.110	35	0.060
35	0.133	37	0.072
37	0.113	39	0.043
39	0.122	41	0.081
41	0.136	43	0.090
43	0.123	45	0.097
45	0.119	47	0.106
47	0.116	51	0.070
49	0.118	53	0.099
51	0.124	55	0.108
53	0.124	57	0.074
55	0.126	59	0.062
57	0.104	61	0.078
59	0.116	63	0.090
61	0.128	65	0.091
63	0.115	67	0.083
65	0.116	69	0.107
67	0.123	71	0.096
69	0.108	73	0.084
71	0.106	75	0.097
73	0.106	77	0.085
75	0.108	79	0.054
77	0.092	81	0.119
79	0.118	83	0.108
81	0.106	85	0.100
83	0.126	87	0.097
85	0.101	89	0.082
87	0.116	91	0.090
89	0.128	93	0.106
91	0.142	95	0.116
93	0.128	97	0.116
95	0.126	99	0.122
97	0.153	104	0.142

Table 6. Reflection coefficients versus time data for experiments 70X-06 and 70X-10 (manual method).--Continued

Experiment 70X-06		Experiment 70X-10	
Cumulative time (hr)	K_R	Cumulative time (hr)	K_R
99	0.123	109	0.144
104	0.116	119	0.144
109	0.141	124	0.154
114	0.122	129	0.133
119	0.152	134	0.138
124	0.197	139	0.188
129	0.177	144	0.150
134	0.140	149	0.152
139	0.162	154	0.160
144	0.148	159	0.168
149	0.142	164	0.164
151	0.152	169	0.166
159	0.184	174	0.183
164	0.192	179	0.154
169	0.168	184	0.187
174	0.160	189	0.148
		194	0.120
		199	0.118
		204	0.096
		209	0.144

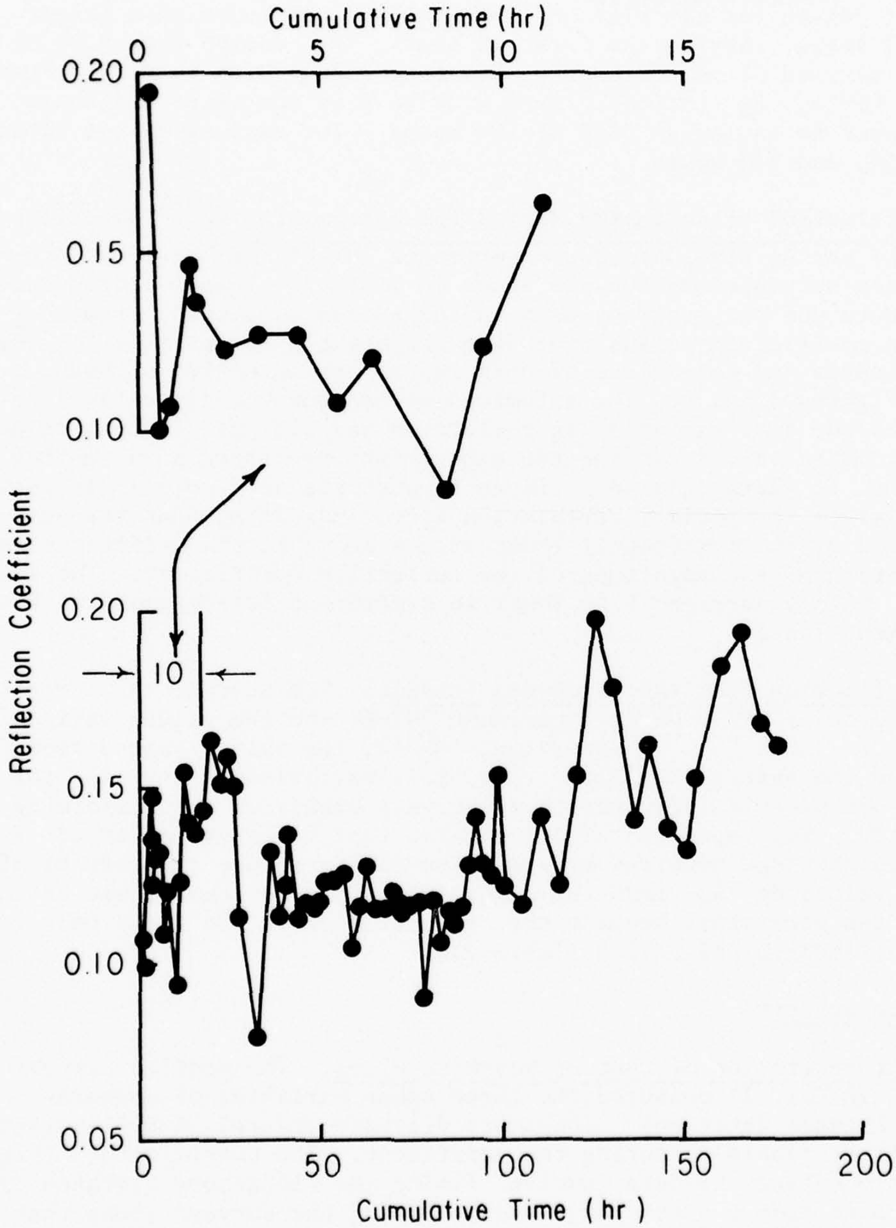

Figure 2. Reflection variability in experiment 70X-06.

95 hours, K_R was lower and varied between 0.09 and 0.14; after 95 hours, K_R fluctuated between 0.12 and 0.20 and, in general, increased. The largest values of K_R occurred at 124 and 164 hours.

(2) Experiment 70X-10. Figure 3 shows K_R versus time for experiment 70X-10 for all time and for the first 10 hours at a larger horizontal scale. During the first 20 hours, K_R varied from 0.10 to 0.16, and between 21 and 89 hours, K_R ranged from 0.04 to 0.12. From 89 to 184 hours, K_R increased from 0.08 to 0.19 and after 184 hours, K_R decreased to as low as 0.10 at 204 hours. The maximum values occurred at 139, 174, and 184 hours.

c. Evaluation of Automated Method for Determining K_R. The reflection coefficient versus time data for experiments 70X-06 and 70X-10 as determined by the automated method are shown in Table 7. Volume I discusses the procedure and the programs used in the automated method. Plots of reflection coefficient versus time from the movable-bed profile for the two experiments, as determined by both manual and automated methods, are shown in Figures 4 and 5. The automated method gave consistently lower values, but the time variation in reflection was similar. Manual values versus automated values for the two experiments are shown in a scatter plot of the K_R data (Fig. 6). Lines through the data points lie above and parallel to the perfect correlation line, indicating that the automated method gives consistently lower values and that the difference was not a function of the magnitude of the reflection coefficient. The automated K_R values averaged 0.05 lower in experiment 70X-06 and 0.04 lower in experiment 70X-10.

d. Reflection from the Fixed-Bed Profile. The average K_R from the fixed-bed profile was 0.05 in experiment 70X-06 and the values varied from 0.05 to 0.06 (Table 7). In experiment 70X-10, the values ranged from 0.03 to 0.07 and the average was 0.04. The small variation in the K_R for the fixed-bed profile indicates that the wave generator was performing consistently. The variation also indicates that the measurement of K_R from a wave envelope recorded by a slow-moving wave gage can vary by ± 0.02. The large values of K_R from the movable bed were not the result of any change in the generator, because the K_R values from the fixed bed remained at their usual values (Table 7).

2. Profile Surveys.

a. Interpretation of Contour Movement Plots. The profile surveys (discussed in Vol. I) measured the three space variables of onshore-offshore distance (station), alongshore distance (range), and elevation at fixed times (Table 2) during the experiment. The CONPLT method (Fig. 7,b) for presenting the data involves fixing the alongshore distance by selecting data from a given range and analyzing the surveys along that range. The surveyed distance-elevation pairs along that range are used to obtain the interpolated position of equally spaced depths; e.g., -0.1, -0.2, and -0.3 on the hypothetical profile in Figure 7(a). These contour positions from each survey are then plotted against time (Fig. 7,b).

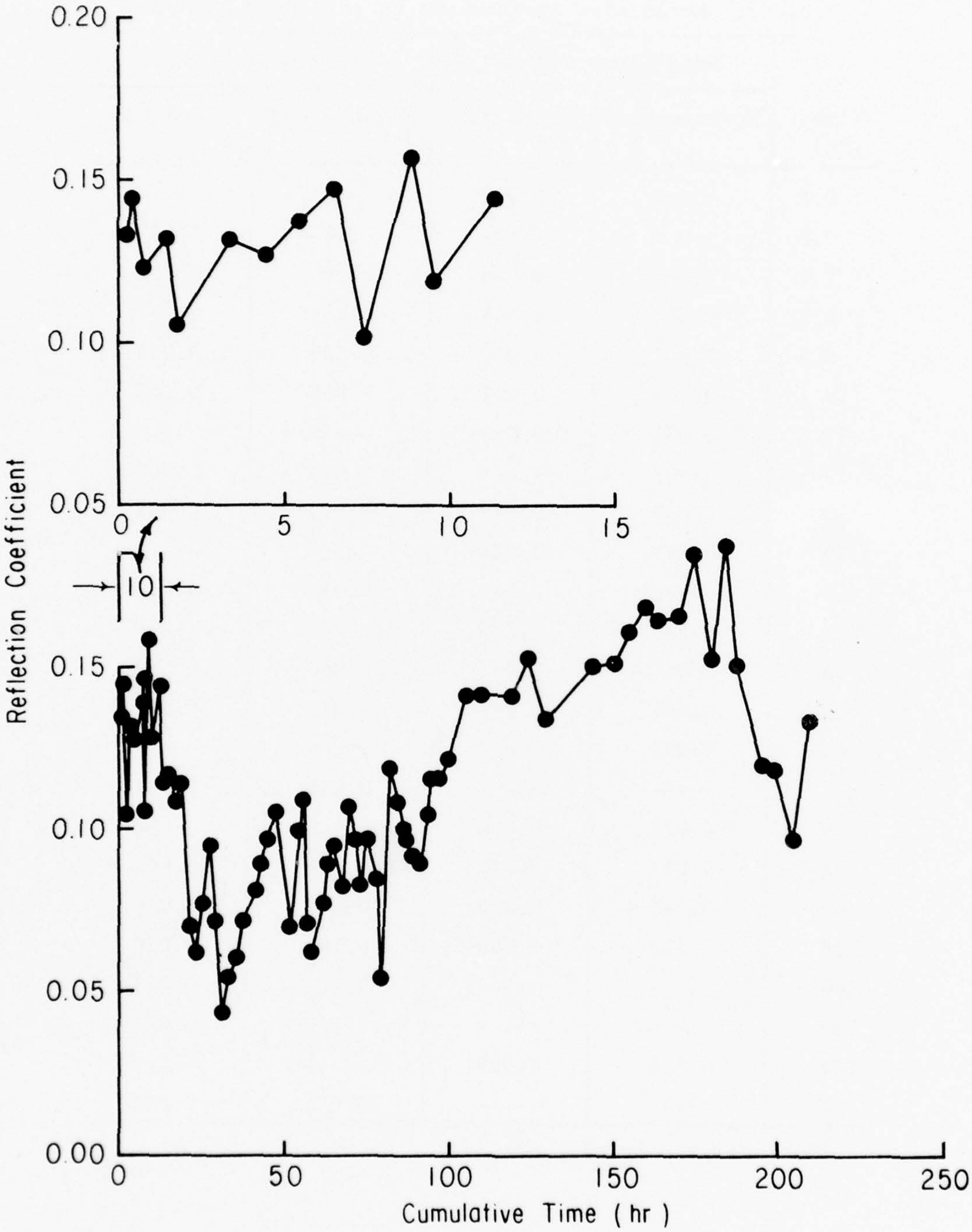

Figure 3. Reflection variability in experiment 70X-10.

Table 7. Reflection coefficient by automated method.

Time (hr)	Experiment 70X-06		Experiment 70X-10	
	Movable bed	Fixed bed	Movable bed	Fixed bed
0.5	0.067	0.059	----[1]	-----
0.8	-----	-----	0.073	0.037
1.8	0.065	0.055	0.090	0.037
4.3	0.048	0.058	0.088	0.037
9.3	0.067	0.052	0.085	0.040
19	0.109	0.064	0.086	0.042
27	0.075	0.055	-----	-----
29	-----	-----	0.044	0.032
39	0.067	0.052	0.011	0.038
49	0.075	0.054	-----	-----
51	-----	-----	0.037	0.050
53	0.082	0.059	-----	-----
59	0.060	0.053	0.043	0.052
65	0.054	0.049	0.054	0.049
69	0.049	0.059	-----	-----
77	-----	-----	0.046	0.051
79	0.071	0.056	-----	-----
89	0.053	0.047	0.039	0.065
99	0.055	0.046	0.075	0.046
124	0.152	0.046	0.107	0.030
149	-----	-----	0.101	0.044
169	-----	-----	0.116	0.044
174	0.123	0.045	-----	-----
194	-----	-----	0.076	0.044

[1]Not analyzed by this method.

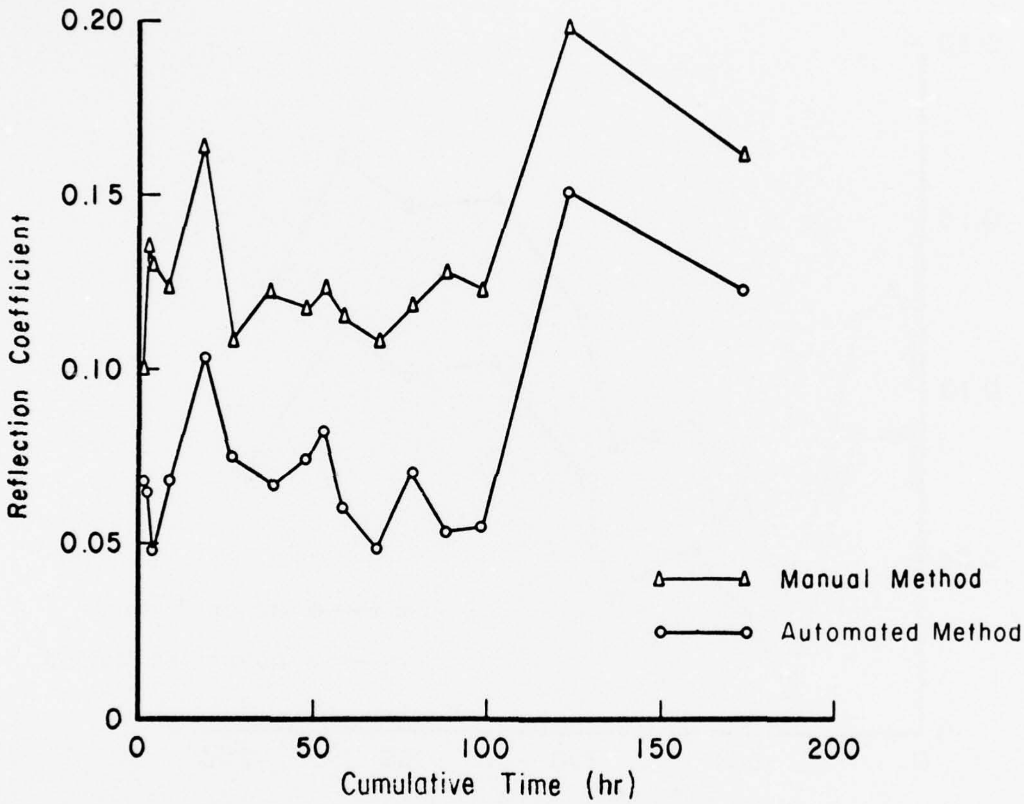

Figure 4. Lower K_R values and similar K_R trend from automated method in experiment 70X-06.

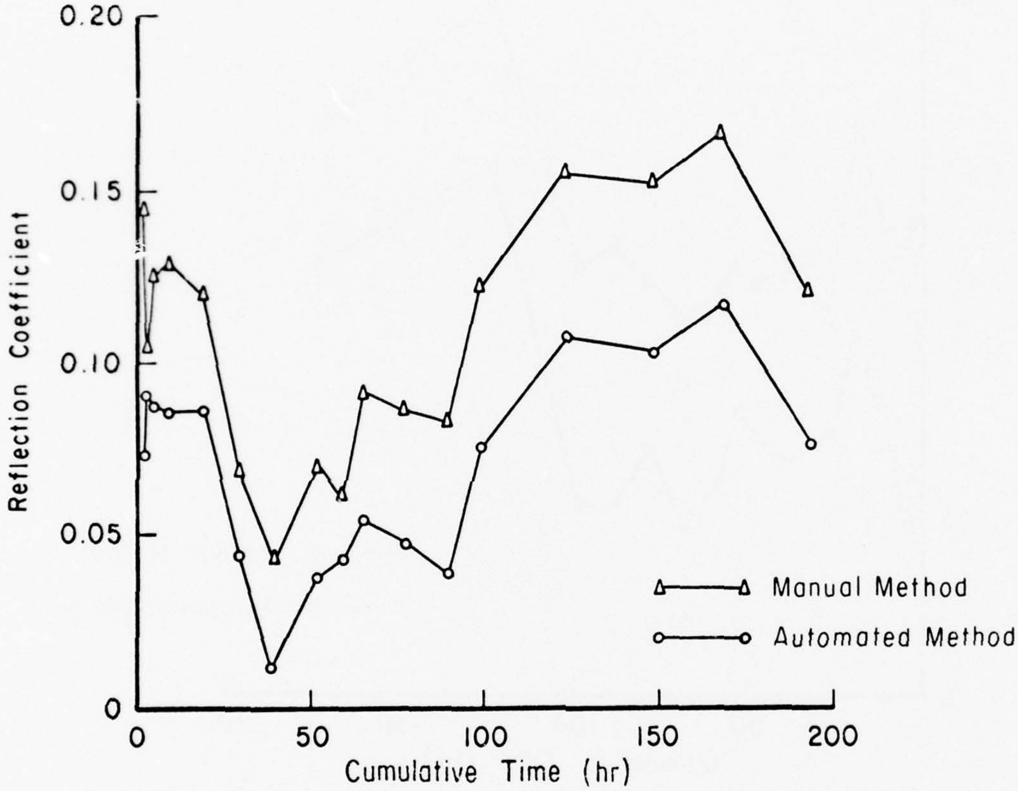

Figure 5. Lower K_R values and similar K_R trend from automated method in experiment 70X-10.

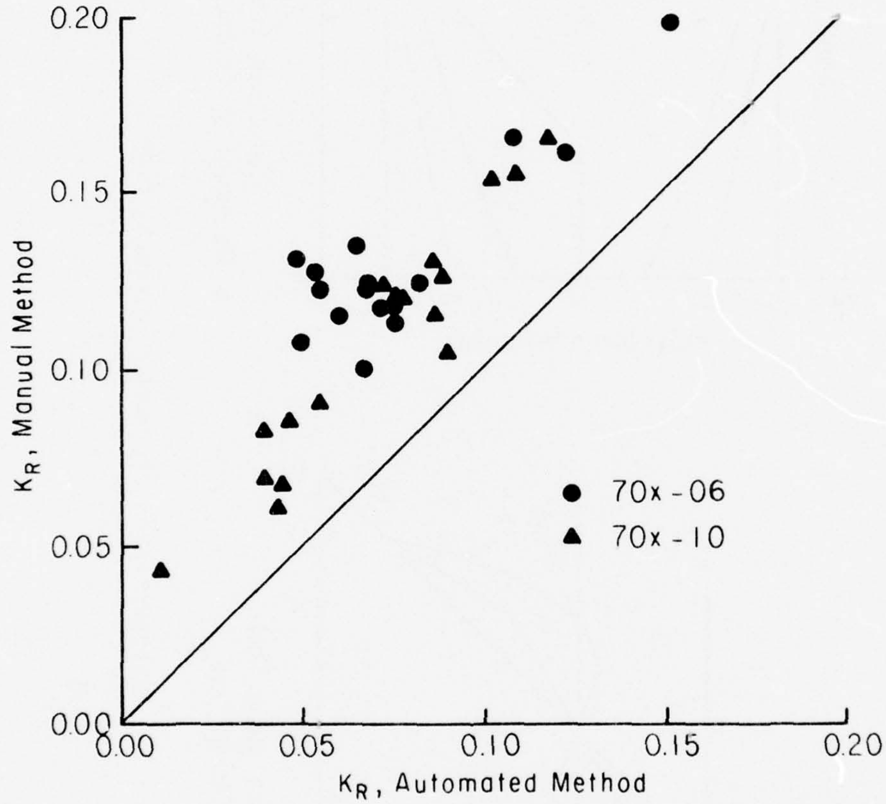

Figure 6. Correlation of manual and automated methods for determining K_R.

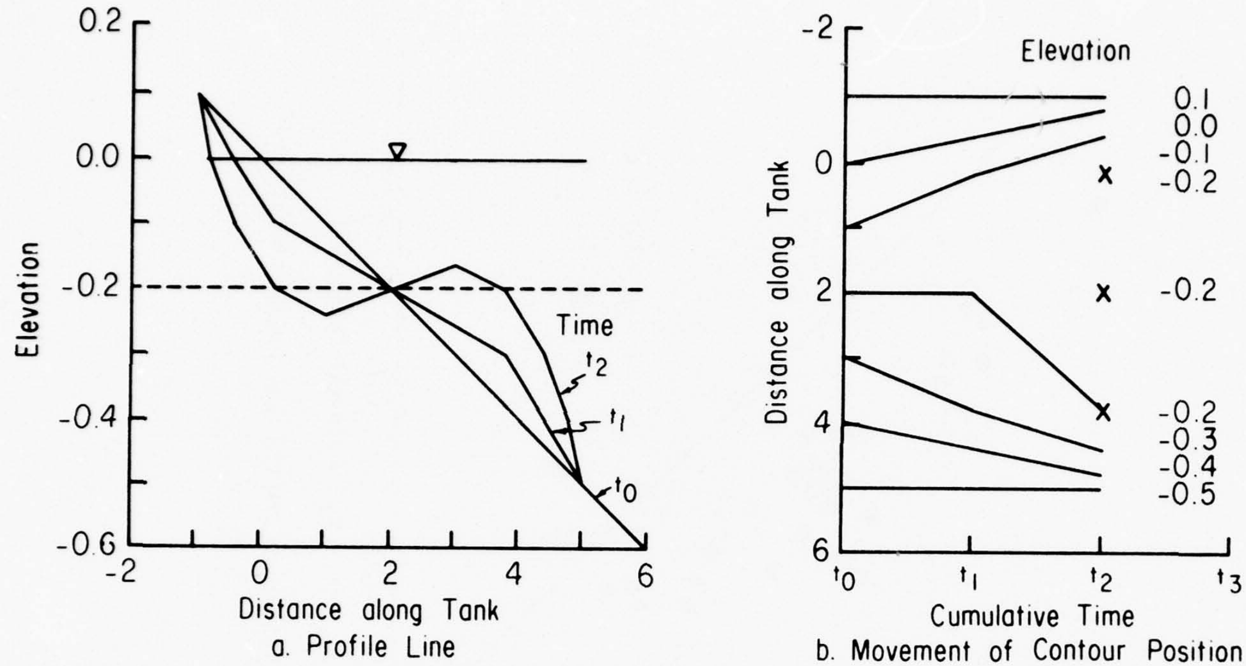

Figure 7. Interpretation of contour movement plots.

A horizontal line in Figure 7(b) represents no change in contour position. An upward-sloping line indicates landward movement of contour position (i.e., erosion); a downward-sloping line indicates deposition. The slope of a line indicates the horizontal rate of erosion or deposition at that elevation. The three x's at time t_2 (Fig. 7,b) indicate multiple contour positions at elevation -0.2 which is shown by the intersection of the dashline with profile t_2 in Figure 7(a).

Three types of contour movement plots included in this study are:

(a) The seawardmost intercepts along one range for any or all depths;

(b) the seawardmost intercepts for one depth along all ranges; and

(c) all contour intercepts along one range, for up to 12 selected depths.

The coordinate system used for the contour movement plots is shown in Figure 8.

The following elevations are referred to in the discussion that follows: ±0.2 foot (±6.1 centimeters), -0.3 foot (-9.1 centimeters), -0.4 foot (-12.2 centimeters), -0.5 foot (-15.2 centimeters), -0.6 foot (-18.3 centimeters), -0.7 foot (-21.3 centimeters), -0.8 foot (-24.4 centimeters), -0.9 foot (-27.4 centimeters), -1.0 foot (-30.5 centimeters), -1.1 feet (-33.5 centimeters), -1.2 feet (-36.6 centimeters), -1.3 feet (-39.6 centimeters), -1.4 feet (-42.7 centimeters), -1.5 feet (-45.7 centimeters), -1.6 feet (-48.8 centimeters), -2.0 feet (-61.0 centimeters), and -2.1 feet (-64.0 centimeters).

b. Profile Zones. Definitions of coastal engineering terms used in LEBS reports conform to Allen (1972) and U.S. Army, Corps of Engineers, Coastal Engineering Research Center (1975). However, the boundary between the foreshore and inshore zones is defined in these reports as the lower limit of backrush (low water line) and is at elevation -0.2 foot.

The seaward edge of the inshore zone is defined as extending from the low water line through the breaker zone. The boundary between the inshore and offshore zones is at elevation -0.8 foot.

A definition sketch of the profile zones is shown in Figure 9. The profile in each experiment developed in a similar sequence. Early profiles (broken line in Fig. 9) had a steep foreshore, a short inshore zone with a longshore bar, and a gently sloping offshore zone. Later profiles (dashline in Fig. 9) also had a steep foreshore zone, but the inshore zone widened to a long, flat shelf which terminated in a relatively steep offshore zone. This development is shown by contour movement plots (Figs. 10 to 17) of the seawardmost contour intercepts for elevations at 0.1-foot-depth increments from +0.2 to -2.1 feet. Figures 10 to 12 are for

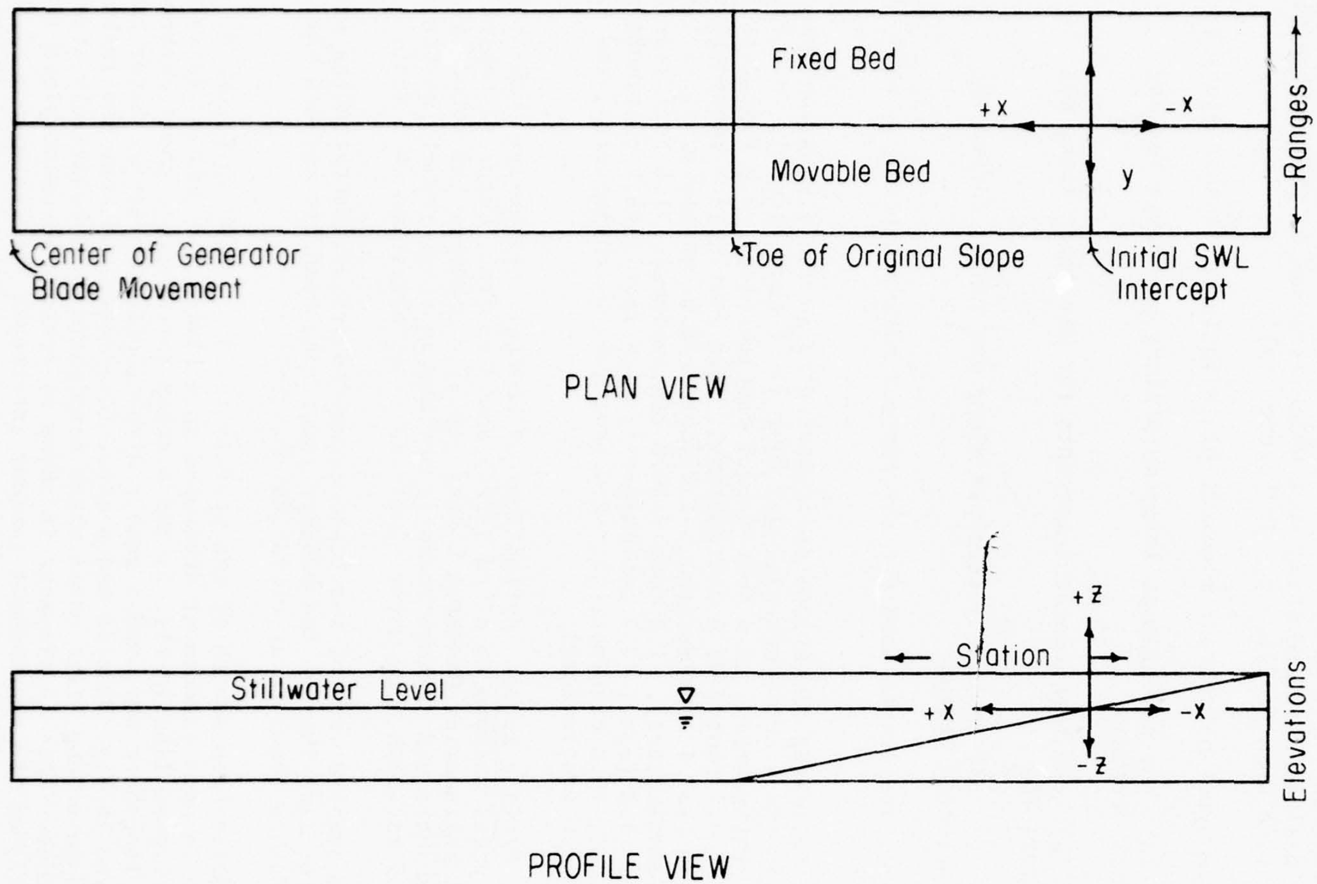

Figure 8. Definition of coordinate system.

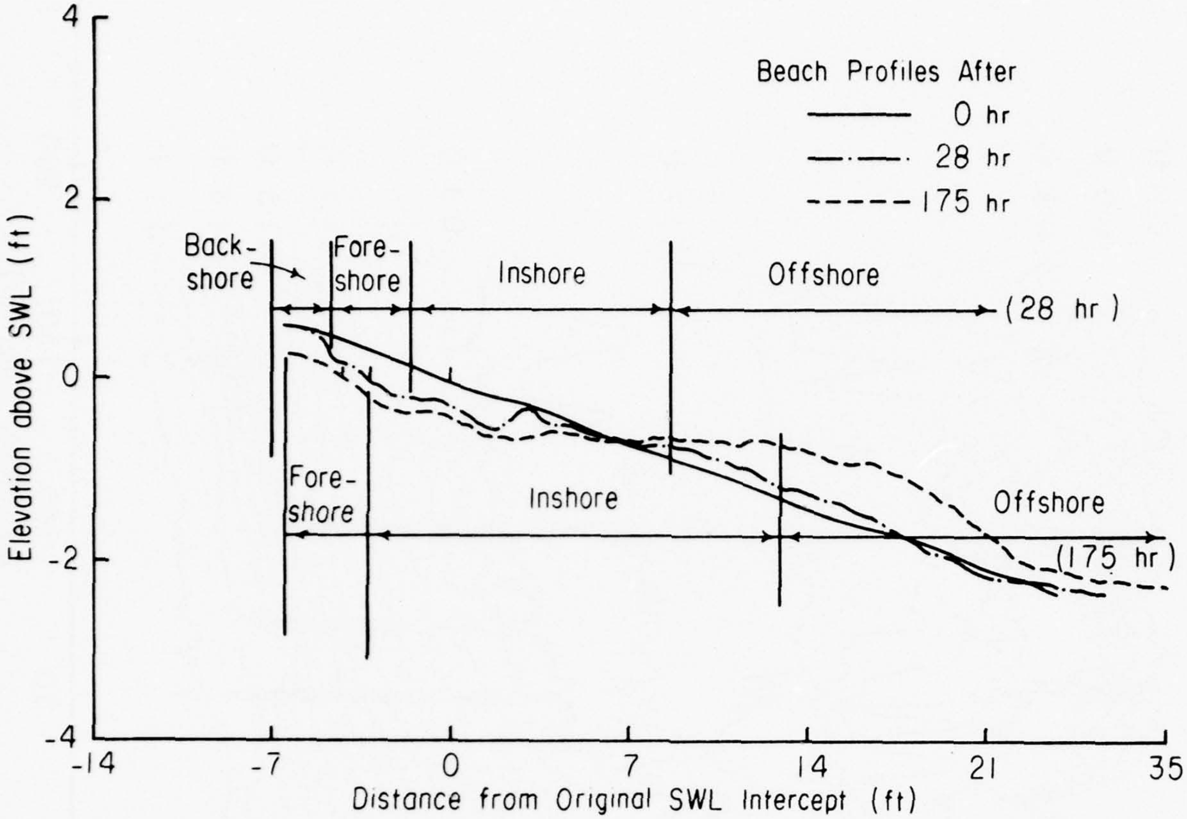

Figure 9. Definition sketch of profile zones (experiment 70X-06).

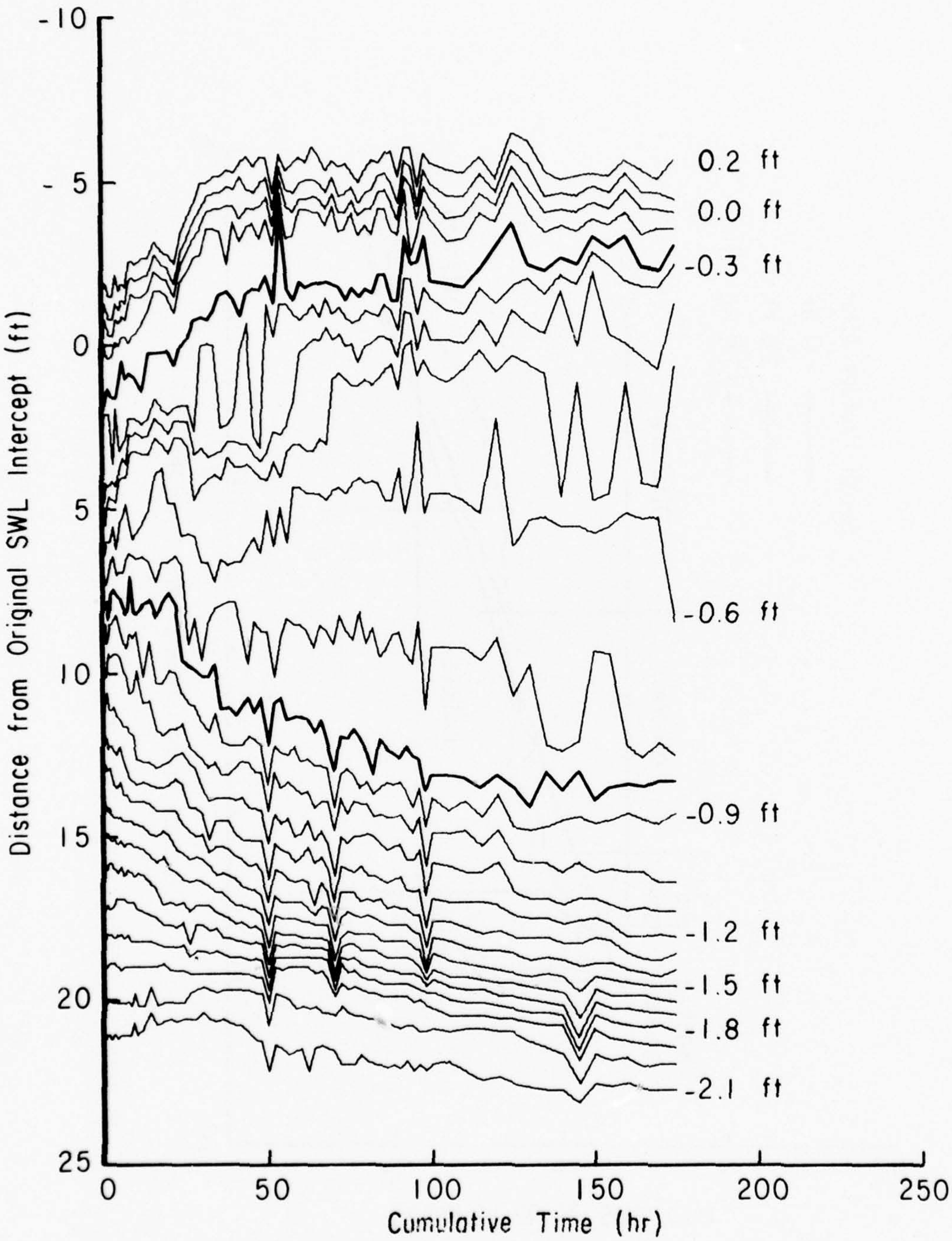

Figure 10. Profile changes along range 1, experiment 70X-06.

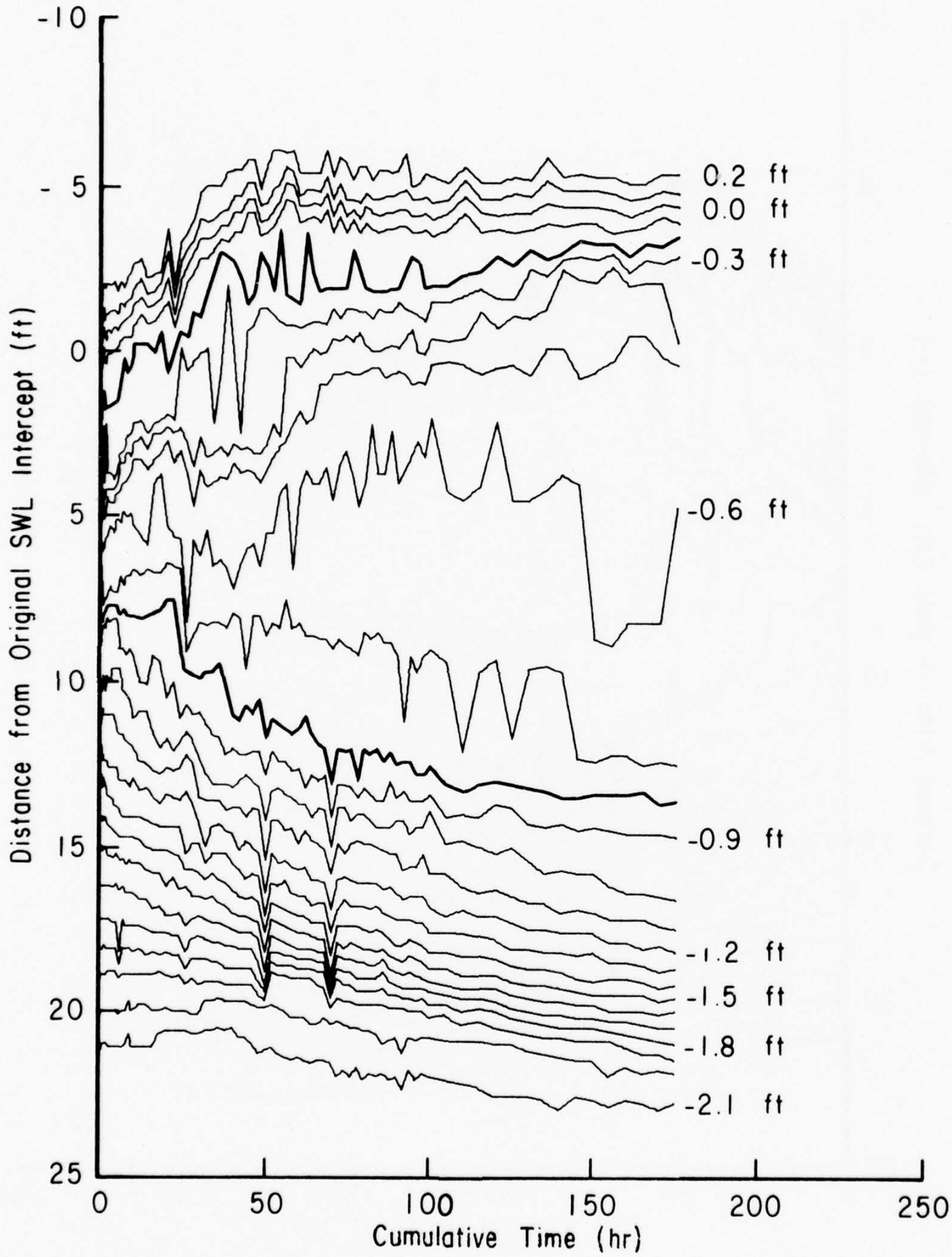

Figure 11. Profile changes along range 3, experiment 70X-06.

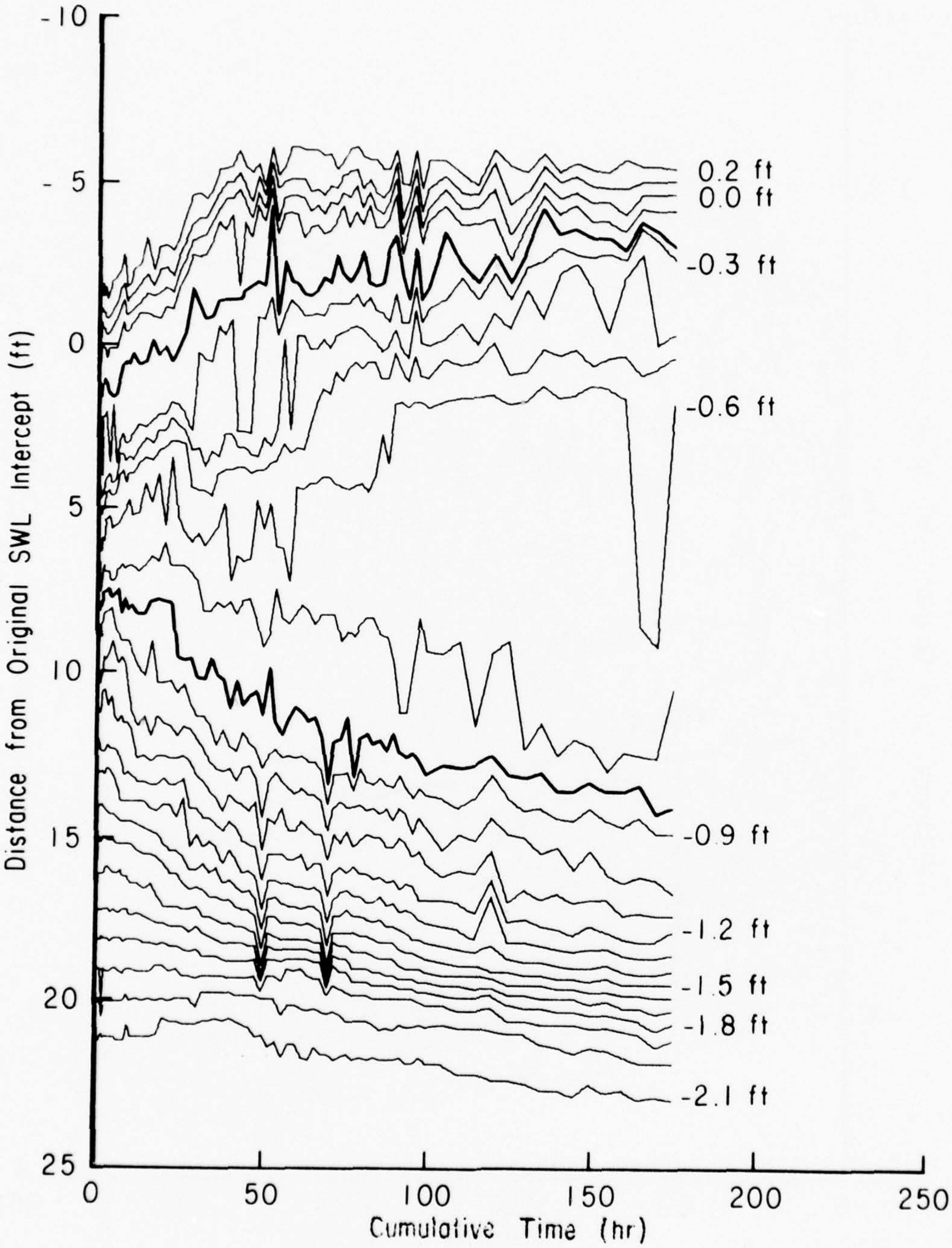

Figure 12. Profile changes along range 5, experiment 70X-06.

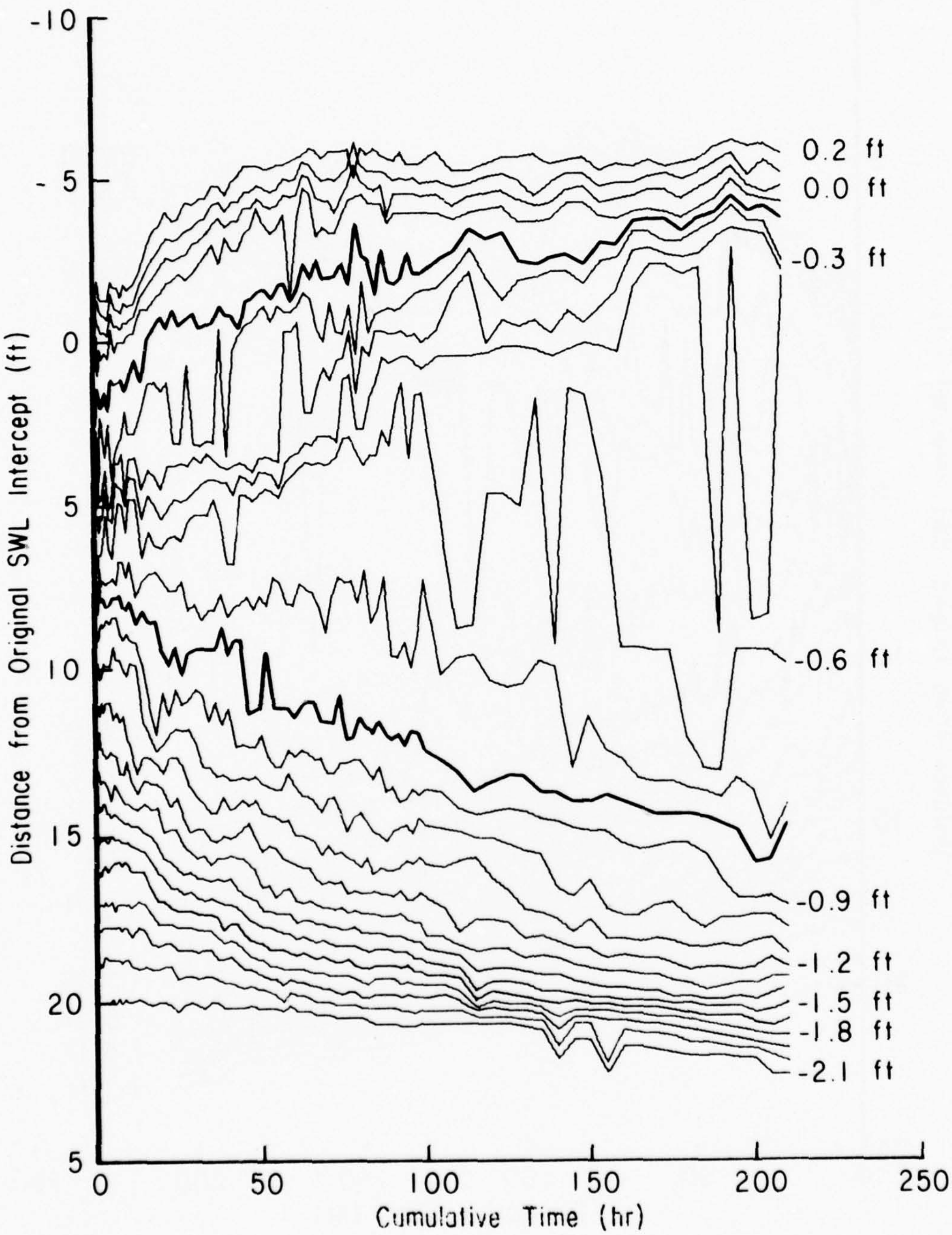

Figure 13. Profile changes along range 1, experiment 70X-10.

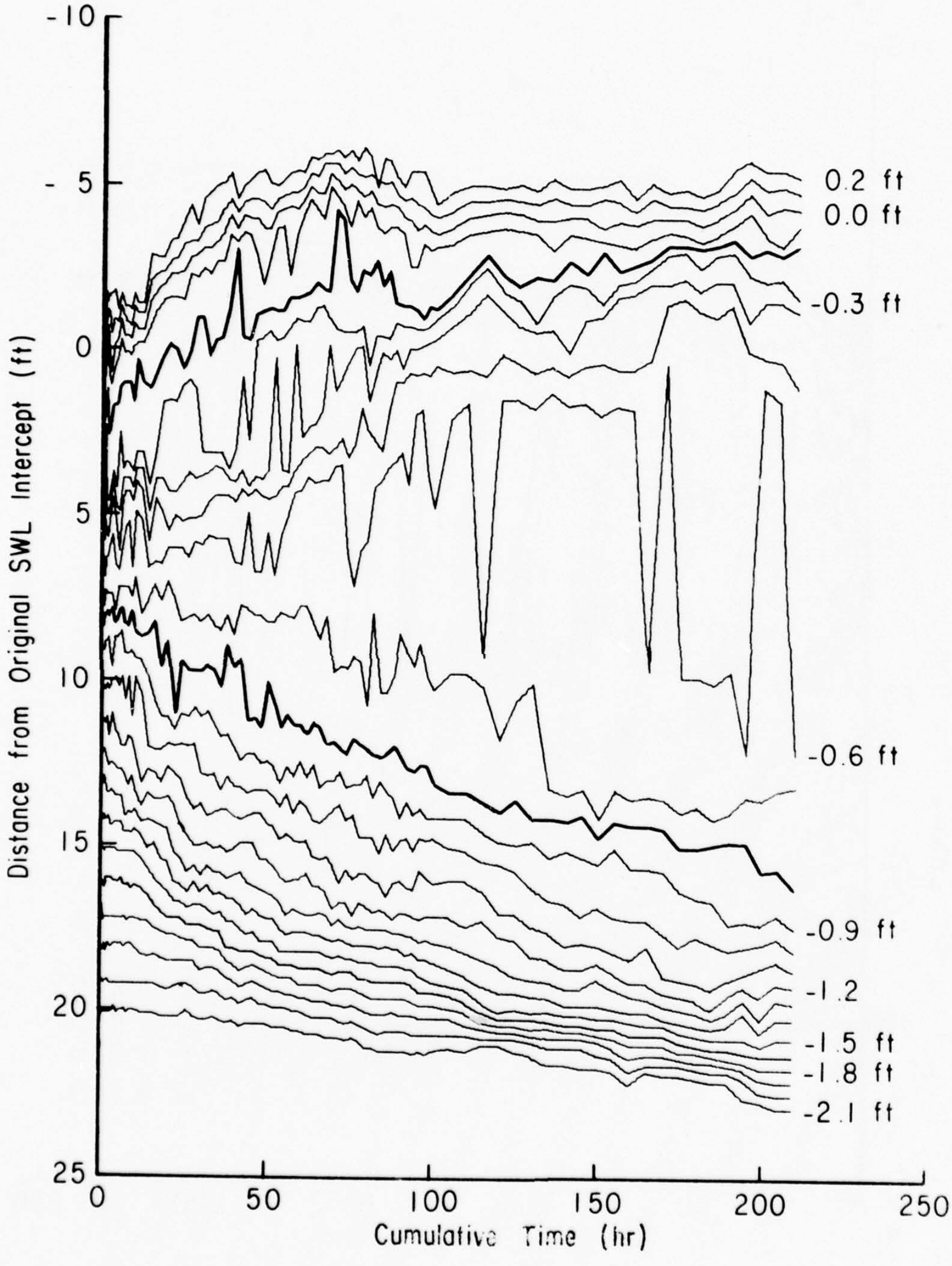

Figure 14. Profile changes along range 3, experiment 70X-10.

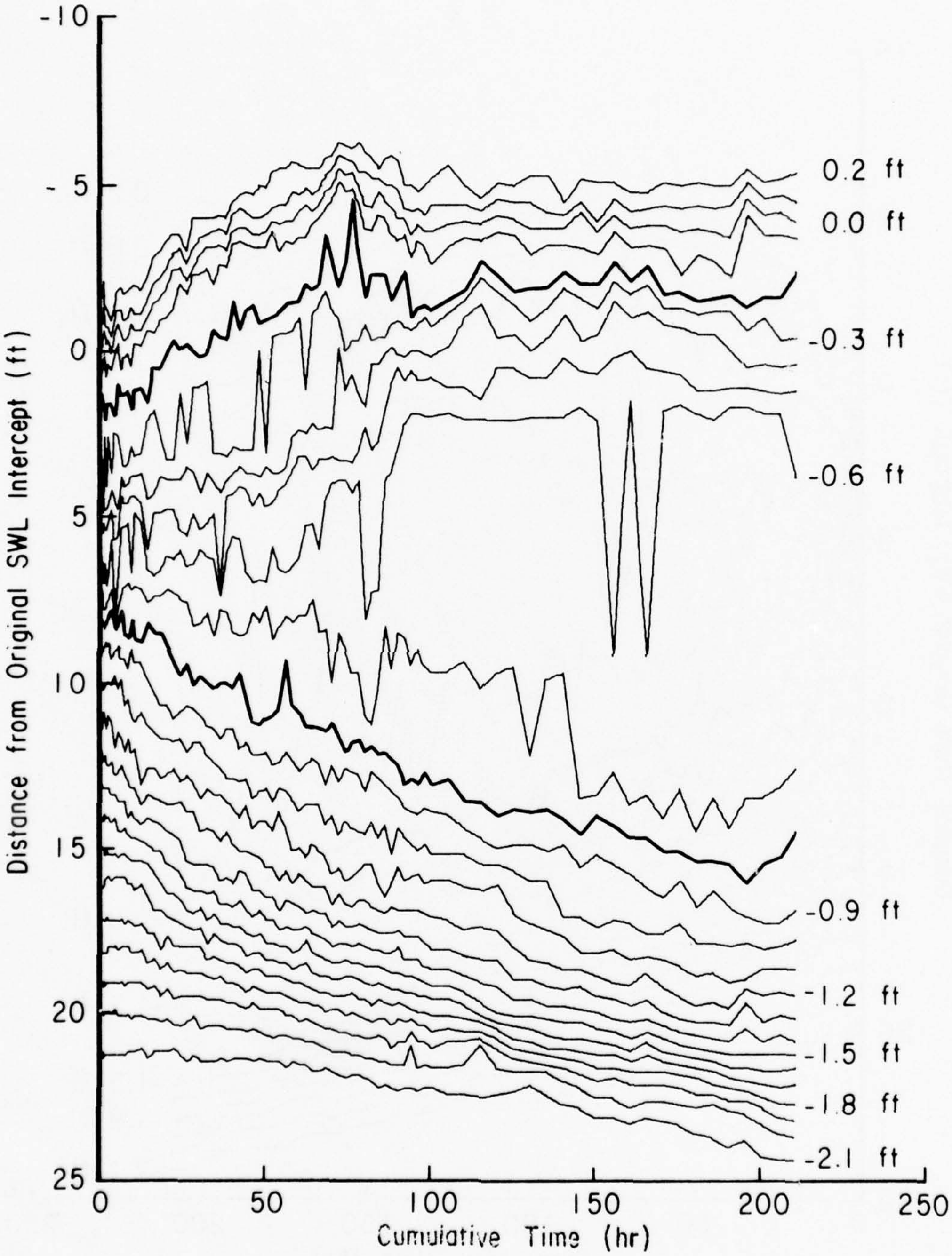

Figure 15. Profile changes along range 5, experiment 70X-10.

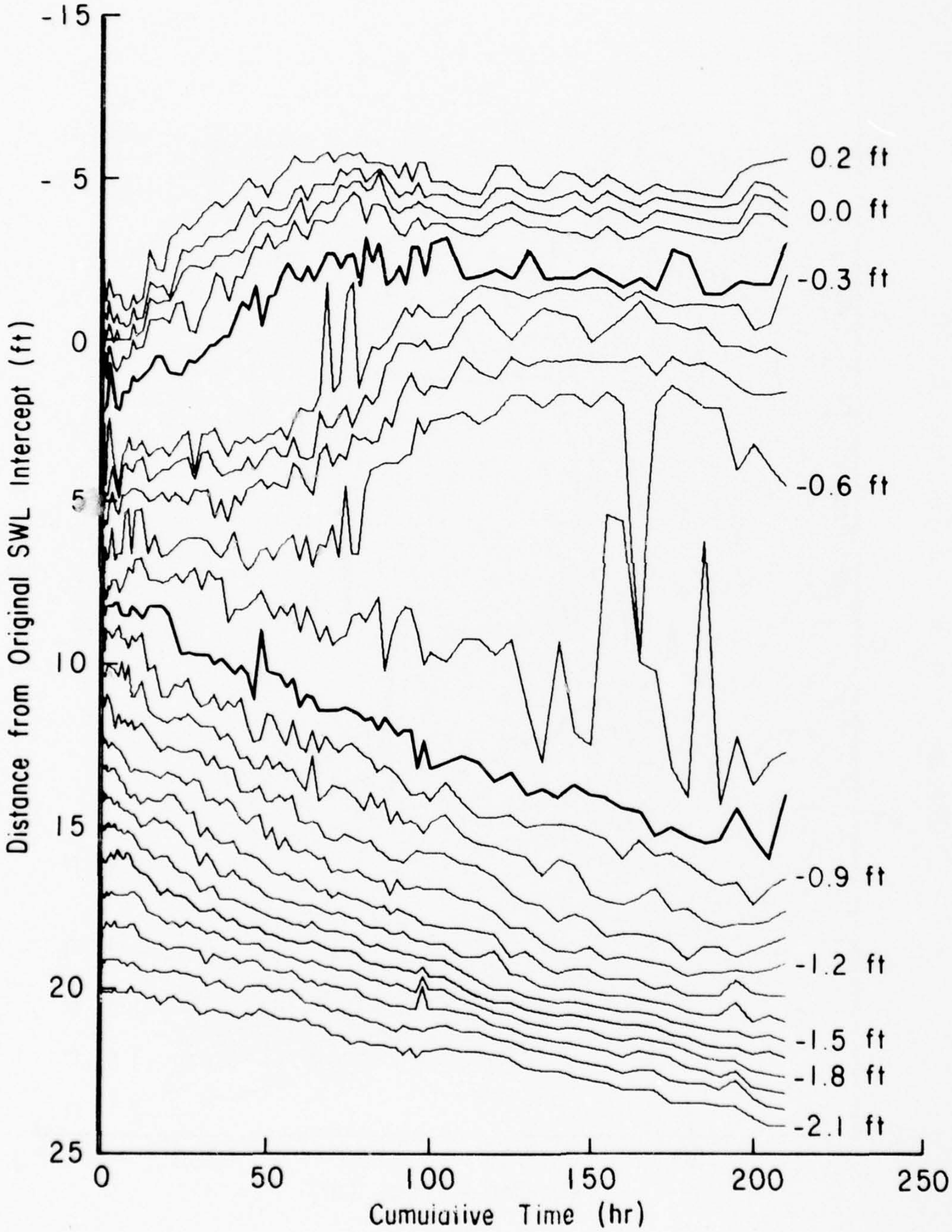

Figure 16. Profile changes along range 7, experiment 70X-10.

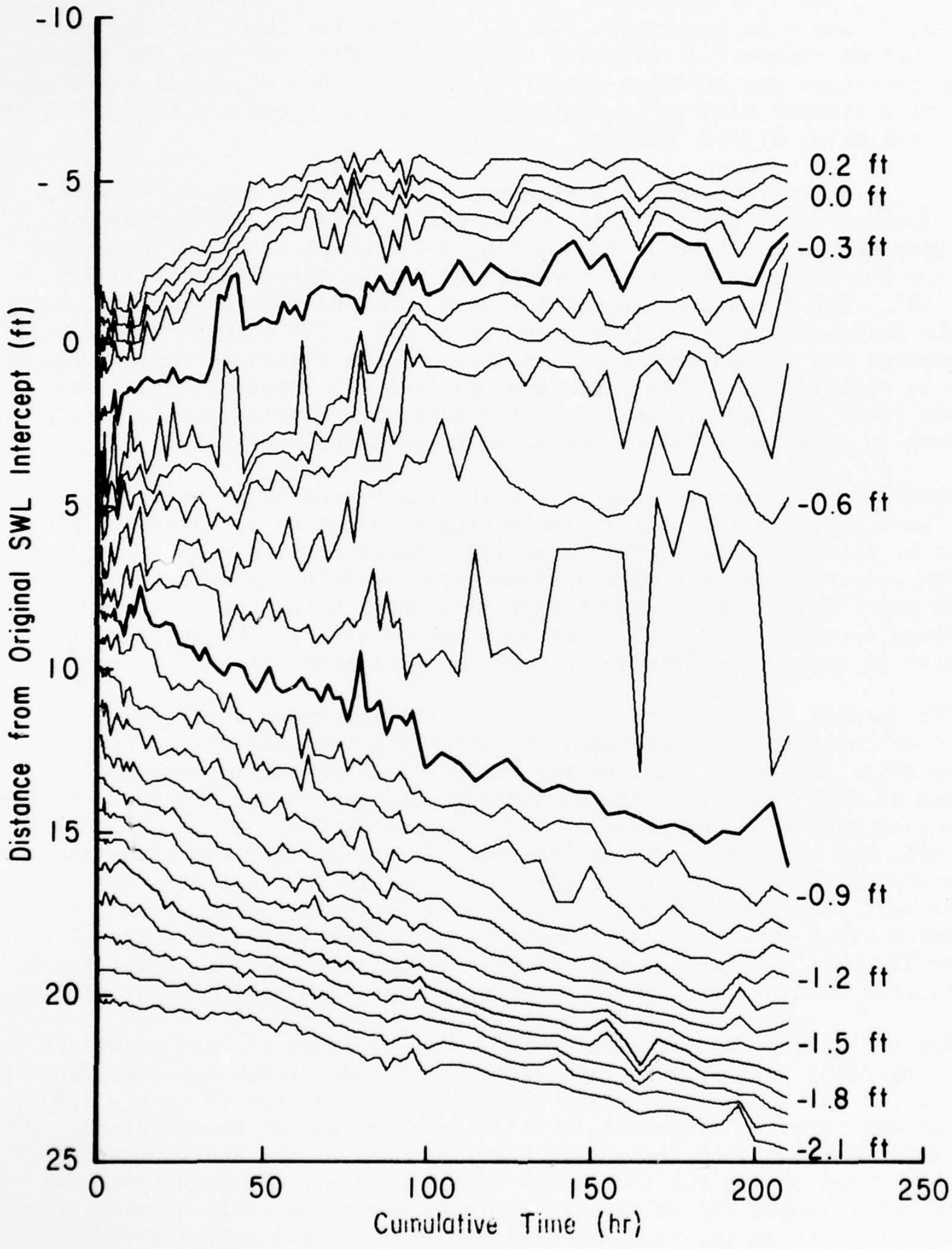

Figure 17. Profile changes along range 9, experiment 70X-10.

ranges 1, 3, and 5 in experiment 70X-06; Figures 13 to 17 are for ranges 1, 3, 5, 7, and 9 in experiment 70X-10. The heavier lines for the -0.2- and -0.8-foot contours distinguish the three profile zones in the figures. In the foreshore and offshore zones the contour lines are close together indicating steeper slopes; in the inshore zone the lines are spaced farther apart indicating flatter slopes.

(1) Foreshore Zone. Within the first hour of each experiment, the foreshore developed the basic shape which it maintained throughout the experiments, as shown in the contour movement plots of the foreshore zone for the first 10 hours of experiments 70X-06 (Fig. 18) and 70X-10 (Fig. 19). The foreshore slope and length remained fairly constant, but not the foreshore position (see Figs. 10 to 17). The foreshore retreated as material was eroded from the foreshore and the backshore (upward-sloping lines in the figures). The foreshore position was stabilized (horizontal contour lines in Figs. 10 to 17) by the backshore nourishment beginning at 54 hours in experiment 70X-06 and 62 hours in experiment 70X-10.

Although the contour lines of the foreshore zone moved together, the lines were not always parallel, indicating a variation in foreshore slope with time at each range (Figs. 10 to 17). Table 8 gives slope values at the SWL intercept for the regularly surveyed profiles in experiments 70X-06 and 70X-10. The steepest slope was about 0.60, but at any one time the slope along any range may have been much flatter. The average slope was 0.19 in experiment 70X-06 and 0.20 in experiment 70X-10.

The lateral variation in the slope of the foreshore developed as a result of concentrations of backwash, which created gullies, or flatter slopes (Fig. 20). The shape of the scarp formation and the schematic diagram of flow in this figure demonstrate the process of erosion. A ridge extends seaward from the point of the scarp (A in Fig. 20) to the intersection with the beach face at its steepest slope. Because the slope and the elevation of the berm crest are greatest along this range, less water washes over the crest and more water rushes directly back to form the reflected wave. The backrush velocity is greatest in the vicinity of C in Figure 20, thus maintaining the steepest slope; the overwash velocity is least, thus eroding less from the scarp and maintaining the point at A.

The part of the uprush that washes over the crest divides along the ridge, proceeds laterally in either direction, and erodes material from the scarp until the landward velocity component reaches zero (B in Fig. 20). The lateral velocity component is still great enough to move sediment and the backwash flows into the gully, carrying some of the sediment eroded from the scarp out to the toe of the foreshore zone. When the backwash in the gully (where the volume is greatest) meets the incident wave, the seaward velocity of the backwash decreases to zero and deposits sediment at the toe of the foreshore. This action causes a longer, flatter region below the SWL intercept at this range. The interference of the backwash with the incident wave decreases the uprush in the region of the gully and prevents sediment from being deposited on the upper part of the beach face, thus maintaining the flatter slope. Because the incident waves meet less

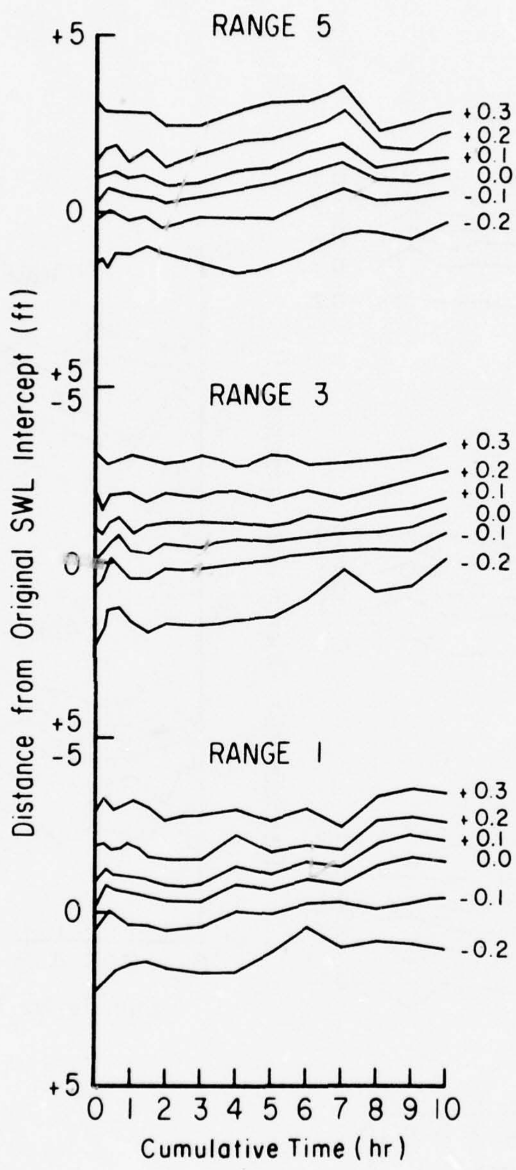

Figure 18. Comparison of initial contour movement in the foreshore zone, experiment 70X-06.

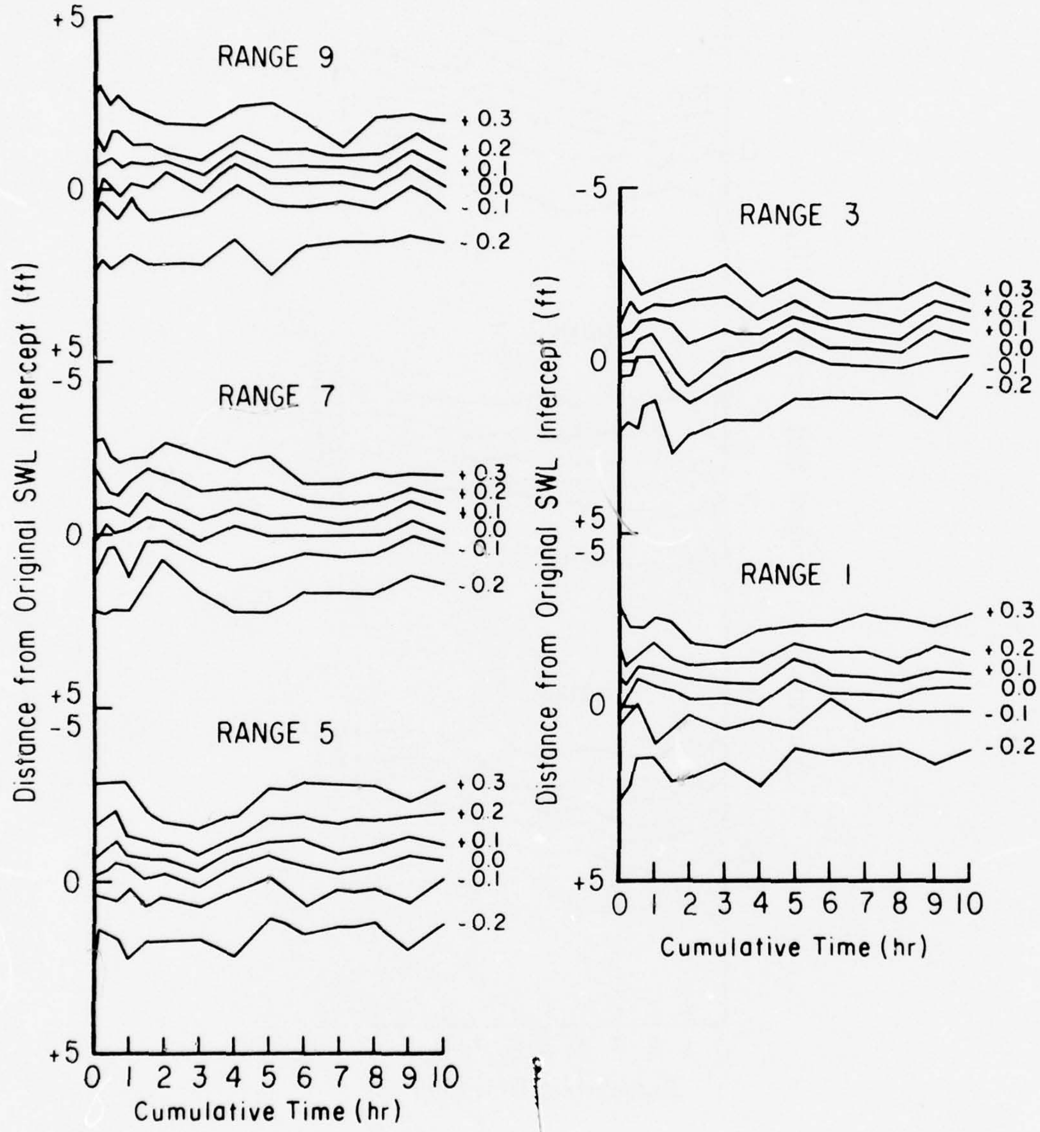

Figure 19. Comparison of initial contour movement in the foreshore zone, experiment 70X-10.

Table 8. Slope of the beach face at the SWL intercept in experiments 70X-06 and 70X-10.

Cumulative time (hr)	Tangent of the slope							
	Range 1		Range 3		Range 5		Range 7	Range 9
	70X-06	70X-10	70X-06	70X-10	70X-06	70X-10	70X-10	
0:00	0.09	0.10	0.10	0.10	0.10	0.12	0.14	0.12
0:10	0.18	0.18	0.14	0.18	0.16	0.22	0.14	0.12
0:25	0.16	0.18	0.20	0.18	0.20	0.16	0.18	0.14
0:40	0.18	0.20	0.18	0.18	0.20	0.12	0.16	0.18
1:00	0.22	0.14	0.20	0.16	0.22	0.20	0.34	0.20
1:30	0.22	0.20	0.12	0.08	0.20	0.20	0.14	0.16
2:00	0.22	0.16	0.18	0.28	0.20	0.20	0.20	0.40
3:00	0.20	0.18	0.14	0.12	0.18	0.20	0.18	0.20
4:00	0.22	0.18	0.18	0.22	0.20	0.20	0.16	0.22
5:00	0.20	0.18	0.22	0.16	0.16	0.22	0.20	0.20
6:00	0.18	0.18	0.18	0.18	0.16	0.14	0.22	0.20
7:00	0.18	0.20	0.18	0.24	0.16	0.16	0.20	0.20
8:00	0.12	0.24	0.20	0.22	0.20	0.20	0.22	0.22
9:00	0.18	0.18	0.20	0.20	0.22	0.16	0.20	0.20
10:00	0.18	0.20	0.16	0.18	0.20	0.18	0.20	0.20
12:00	0.18	0.20	0.16	0.20	0.32	0.18	0.20	0.20
14:00	0.18	0.24	0.24	0.18	0.18	0.22	0.20	0.20
16:00	0.12	0.20	0.22	0.22	0.20	0.16	0.22	0.12
18:00	0.20	0.16	0.22	0.24	0.14	0.16	0.20	0.16
20:00	0.22	0.18	0.10	0.20	0.16	0.10	0.58	0.20
22:00	0.24	0.16	0.22	0.18	0.18	0.18	0.18	0.22
24:00	0.22	0.16	0.18	0.14	0.20	0.22	0.18	0.16
26:00	0.20	0.14	0.22	0.22	0.20	0.20	0.20	0.22
28:00	0.18	0.12	0.24	0.20	0.22	0.58	0.16	0.22
30:00	0.16	0.22	0.22	0.18	0.16	0.18	0.12	0.18
32:00	0.18	0.18	0.20	0.18	0.16	0.20	0.12	0.20
34:00	0.16	0.20	0.22	0.20	0.16	0.20	0.22	0.18
36:00	0.18	0.14	0.22	0.16	0.20	0.18	0.16	0.24
38:00	0.10	0.16	0.22	0.18	0.22	0.22	0.12	0.30
40:00	0.20	0.22	0.20	0.20	0.22	0.20	0.18	0.20
42:00	0.14	0.16	0.20	0.20	0.20	0.16	0.16	0.34
44:00	0.18	0.14	0.22	0.18	0.18	0.16	0.10	0.24
46:00	0.18	0.20	0.22	0.18	0.16	0.22	0.24	0.20
48:00	0.12	0.22	0.20	0.10	0.20	0.22	0.20	0.18
50:00	0.18	0.30	0.24	0.16	0.16	0.22	0.22	0.12
52:00	0.22	0.20	0.16	0.20	0.20	0.42	0.22	0.20
54:00	0.22	0.20	0.20	0.22	0.22	0.18	0.22	0.18
56:00	0.14	0.18	0.18	0.14	0.24	0.22	0.20	0.22
58:00	0.18	0.22	0.24	0.20	0.20	0.14	0.38	0.26
60:00	0.22	0.16	0.22	0.26	0.20	0.20	0.18	0.18
62:00	0.14	0.20	0.26	0.28	0.18	0.18	0.14	0.20
64:00	0.20	0.26	0.28	0.20	0.18	0.22	0.14	0.20
66:00	0.20	0.22	0.22	0.12	0.18	0.22	0.22	0.20
68:00	0.22	0.08	0.20	0.26	0.18	0.14	0.20	0.14
70:00	0.20	0.12	0.20	0.18	0.16	0.18	0.16	0.12
72:00	0.18	0.08	0.20	0.18	0.18	0.26	0.18	0.14
74:00	0.20	0.20	0.20	0.20	0.18	0.20	0.22	0.46
76:00	0.26	0.14	0.36	0.32	0.14	0.20	0.36	0.34
78:00	0.20	0.22	0.22	0.20	0.14	0.20	0.22	0.32
80:00	0.20	0.16	0.24	0.20	0.20	0.16	0.34	0.22
82:00	0.18	0.26	0.22	0.14	0.20	0.18	0.20	0.18
84:00	0.20	0.20	0.18	0.14	0.20	0.04	0.60	0.18
86:00	0.18	0.18	0.18	0.14	0.20	0.22	0.22	0.10
88:00	0.16	0.18	0.20	0.22	0.16	0.16	0.18	0.16
90:00	0.18	0.20	0.20	0.20	0.20	0.14	0.20	0.16
92:00	0.20	0.20	0.16	0.14	0.20	0.22	0.22	0.20
94:00	0.14	0.20	0.18	0.16	0.22	0.14	0.20	0.48
96:00	0.22	0.20	0.20	0.20	0.16	0.20	0.18	0.16
98:00	0.20	0.24	0.20	0.18	0.20	0.20	0.32	0.16
100:00	0.20	0.20	0.20	0.22	0.20	0.12	0.26	0.20
105:00	0.14	0.20	0.20	0.20	0.20	0.18	0.48	0.24
110:00	0.18	0.18	0.20	0.22	0.20	0.18	0.22	0.22

Table 8. Slope of the beach face at the SWL intercept in experiments 70X-06 and 70X-10.-Continued

Cumulative time (hr)	Tangent of the slope							
	Range 1		Range 3		Range 5		Range 7	Range 9
	70X-06	70X-10	70X-06	70X-10	70X-06	70X-10	70X-10	
115:00	0.18	0.22	0.20	0.20	0.20	0.20	0.22	0.18
120:00	0.22	0.22	0.18	0.22	0.12	0.20	0.16	0.18
125:00	0.22	0.20	0.20	0.20	0.12	0.20	0.22	0.20
130:00	0.12	0.16	0.20	0.22	0.20	0.22	0.24	0.24
135:00	0.20	0.34	0.14	0.14	0.22	0.22	0.24	0.18
140:00	0.18	0.20	0.24	0.20	0.22	0.22	0.18	0.22
145:00	0.20	0.22	0.20	0.20	0.20	0.34	0.18	0.18
150:00	0.22	0.22	0.20	0.18	0.18	0.34	0.20	0.18
155:00	0.18	0.24	0.16	0.18	0.18	0.18	0.18	0.20
160:00	0.16	0.16	0.18	0.18	0.22	0.22	0.20	0.14
165:00	0.18	0.18	0.20	0.16	0.22	0.18	0.22	0.32
170:00	0.20	0.20	0.26	0.20	0.22	0.16	0.22	0.26
175:00	0.24	0.16	0.22	0.20	0.20	0.12	0.20	0.22
180:00	----	0.16	----	0.20	----	0.12	0.22	0.18
185:00	----	0.16	----	0.20	----	0.16	0.22	0.20
190:00	----	0.18	----	0.20	----	0.08	0.20	0.20
195:00	----	0.24	----	0.18	----	0.20	0.18	0.10
200:00	----	0.36	----	0.12	----	0.20	0.20	0.18
205:00	----	0.18	----	0.16	----	0.16	0.22	0.18
210:00	----	0.24	----	0.18	----	0.18	0.24	0.20

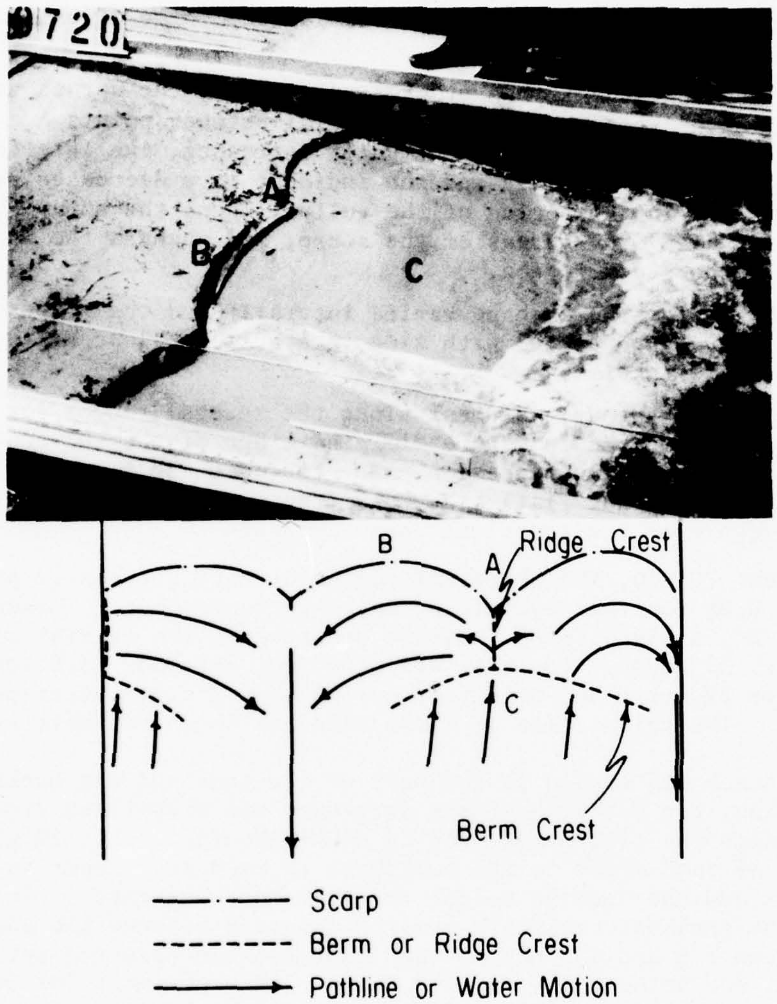

Figure 20. Three-dimensional flow in the foreshore zone.

interference in the steeper region near C (in Fig. 20), the uprush between A and B is greater, erodes farther into the scarp, and carries more sediment into the gully, further generating the three-dimensional system of flow and erosion.

After this erosion process has progressed a while, the uprush no longer has sufficient velocity to erode material between points A and B (Fig. 20), the sediment moving into the gully decreases, the interference between the backwash in the gully and the incident wave decreases, and the uprush increases in the region of the gully. Then, the uprush begins to erode material from other areas of the scarp, and changes the positions of the gully and the steep region.

Even though the foreshore shape varied laterally and the slope of the foreshore along any range varied with time, the average slope of the foreshore did not vary with time.

The shoreline (0 contour) movement along the several ranges for the two experiments is compared in Figure 21. The slope of the 0 contour line indicates the shoreline recession rate. Because the slope of the backshore was 0.10 (and not flat), the volume rate of erosion was proportional to the square of the shoreline recession rate.

In experiment 70X-10, the shoreline recession rate between 12 and 62 hours averaged 0.08 foot per hour (2.4 centimeters per hour). However, in experiment 70X-06, a significant increase occurred in the retreat rate during the first 50 hours. The rate was 0.06 foot per hour (1.8 centimeters per hour) before 22 hours and 0.14 foot per hour (4.2 centimeters per hour) after 22 hours. The calculation of these rates is shown in Table 9.

After the beach had eroded to the back of the tank and the backshore nourishment began, the position of the foreshore was stabilized (the Appendix discusses the procedures used in nourishment). Table 10 gives data on weight of sand added to the backshore in each experiment in 10-hour increments and the average weight for a 10-hour increment. In experiment 70X-10, the greatest backshore erosion occurred between 130 and 150 hours and between 170 and 180 hours; the least erosion occurred between 62 and 70 hours and between 160 and 170 hours. In experiment 70X-06, the greatest erosion was between 90 and 100 hours with minimal erosion between 60 and 70 hours and between 170 and 175 hours.

(2) Inshore Zone. Within the first hour of each experiment, a longshore bar developed at the shoreward end of the inshore zone between elevations -0.2 and -0.5 foot. Later, but at different times, the bar disappeared, the area between -0.2 and -0.5 foot steepened, and a long, flat shelf developed between elevations -0.5 and -0.8 foot. The shelf continued to grow in length for the remainder of the experiments. Changes in the inshore zone for each experiment are divided into an inner region (between -0.2 and -0.5 foot) and an outer region (between -0.5 and -0.8 foot).

(a) Inner Region (Experiment 70X-06). The movement of all contour intercepts in the inshore zone along the three ranges for experiment

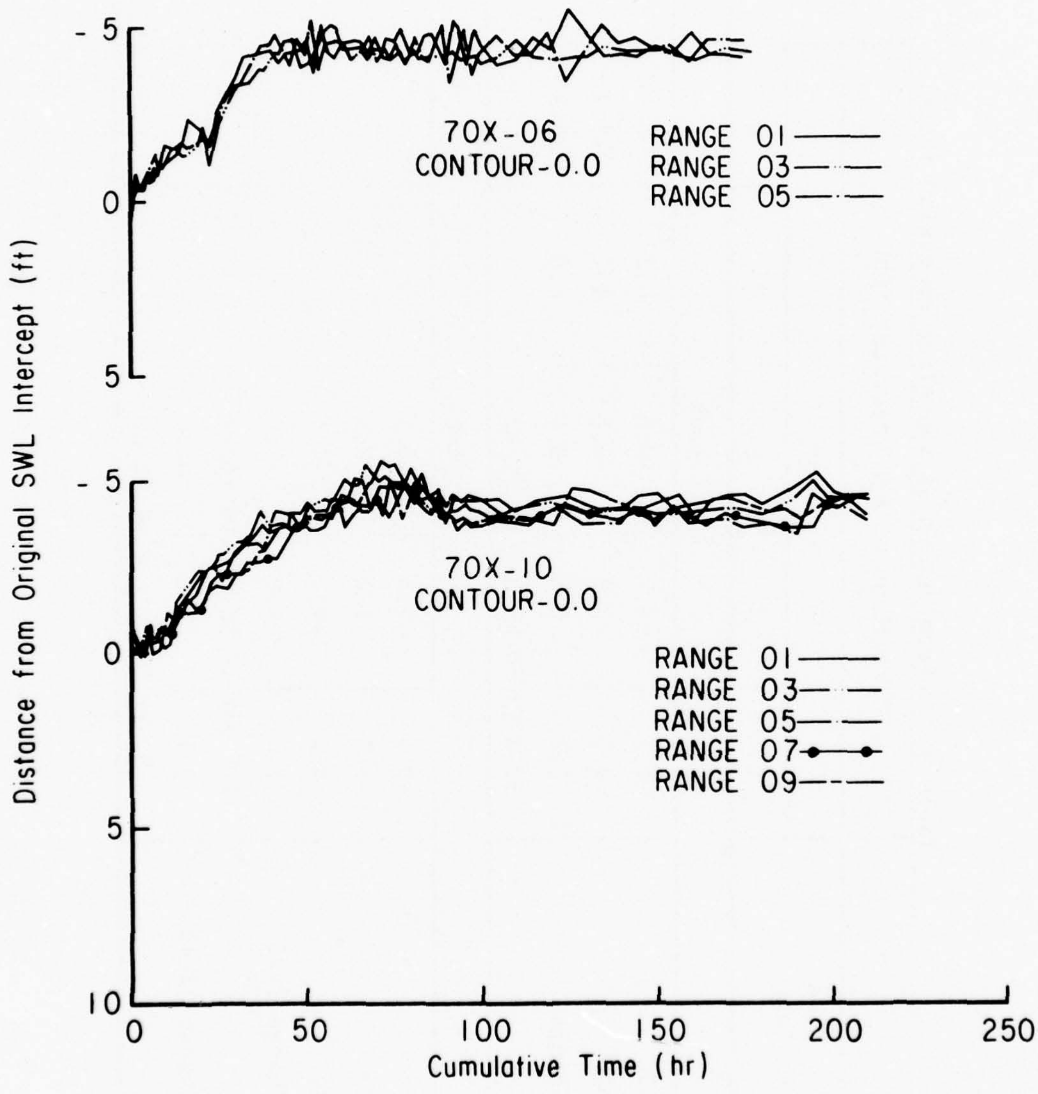

Figure 21. Comparison of the shoreline (0 contour) movement in experiments 70X-06 and 70X-10.

Table 9. Determination of shoreline recession rates.

Time (hr)	Position of SWL intercept (ft) — Range 1	3	5	7	9	Avg. change
10-ft tank						
12	-0.7	-0.7	-0.6	-0.2	0	
62	-4.5	-4.5	-4.0	-4.2	-3.9	
Change	3.8	3.8	3.4	4.0	3.9	3.78
	3.78 ft/50 hr = 0.08 ft/hr					
6-ft tank						
2	-0.3	-0.3	-0.3			
22	-1.5	-1.2	-0.3			
42	-4.0	-4.2	-4.4			
Change 2-22	1.2	0.9	1.2			1.1
	1.1 per 20 hr = 0.06 ft/hr					
Change 22-42	2.5	3.0	2.9			2.8
	2.8 per 20 hr = 0.14 ft/hr					

Table 10. Weight of sand added to backshore (in 10-hour intervals).

Time interval (hr)	Weight (lb)	
	10-ft tank	6-ft tank
00:00 to 10:00	0	0
10:01 to 20:00	0	0
20:01 to 30:00	0	0
30:01 to 40:00	0	0
40:01 to 50:00	0	0
50:01 to 60:00	0	135.13
60:01 to 70:00	140.19	85.00
70:01 to 80:00	341.31	120.75
80:01 to 90:00	217.94	281.56
90:01 to 100:00	315.63	416.25
100:01 to 110:00	302.63	177.56
110:01 to 120:00	254.50	202.69
120:01 to 130:00	340.00	265.13
130:01 to 140:00	451.00	243.38
140:01 to 150:00	434.13	200.81
150:01 to 160:00	262.19	167.31
160:01 to 170:00	168.50	224.56
170:01 to 180:00	439.13	44.63
180:01 to 190:00	279.75	
190:01 to 200:00	295.81	
200:01 to 210:00	200.00	
Totals	4,442.71	2,564.76
Avg. for 10-hr increment	296.18	205.18

70X-06 is shown in Figures 22, 23, and 24; the movement of selected individual contours along the three ranges is compared in Figure 25.

During the first 10 minutes of testing a bar formed at station 4 by plunging breakers, and within 4 hours the elevation of the bar had reached -0.3 foot (triangles in Figs. 22, 23, and 24). Between 4 and 8 hours the bar moved shoreward and then remained at station 2 until 22 hours. After 22 hours the bar moved seaward to station 2.5 and the elevation fluctuated between -0.3 and -0.4 foot, as indicated in the figures by the shifting of the seawardmost contour for -0.3 foot. After 54 hours the bar disappeared, evidenced by the shoreward movement of the -0.4-foot contour. The inner region maintained a fairly stable, gently sloping shape from 66 to 135 hours and after 135 hours developed a steep slope (close spacing of the -0.2-, -0.3-, and -0.4-foot contours in Figs. 22, 23, and 24).

The movements of the -0.2- and -0.4-foot contours are compared in Figure 25. No lateral variation apparently occurred in the changes of the inner region, other than minor differences in the elevation of the bar crest between 22 and 54 hours (see comparison of the -0.2- and -0.4-foot contours for the three ranges in Fig. 25).

(b) Outer Region (Experiment 70X-06). During the first 22 hours little change occurred in this region, only the slight erosion evidenced by the retreat of the -0.5-foot contour (Figs. 22, 23, and 24) as the bar formed in the inner region. After 22 hours the deposition of sand in the offshore was sufficient to move the -0.8-foot contour in the seaward direction and thus form a nearly flat shelf between the 0.5- and 0.8-foot depths. After the large deposition between 22 and 26 hours (seaward movement of the -0.6-, -0.7-, and -0.8-foot contours), the shelf in the outer inshore continued to grow as more material was deposited offshore, as indicated by the seaward movement of the -0.8-foot contour. The shoreward movements of the -0.5- and -0.6-foot contours follow the erosion of the bar in the inner region and result in the further development of the flat shelf in the outer region.

The shoreward edge of the shelf or outer region stabilized after 66 hours, and the seaward edge (-0.8-foot contour) reached equilibrium at 100 hours. After 100 hours, the seaward movements of the -0.6- and -0.7-foot contours indicated that some material was being deposited in this outer region. What might be considered small bars (difference between crest and trough elevations was generally less than 0.2 foot) were formed at stations 8.5 and 4.5 (Figs. 22, 23, and 24).

The only significant lateral variations in this outer inshore was the depth over the bars at stations 8.5 and 4.5. After 135 hours the elevation of the bar at station 4.5 was -0.5 foot along range 1 (Fig. 22), -0.6 foot along range 3 (Fig. 23), and -0.7 foot along range 5 (Fig. 24); the elevation at station 8.5 was generally -0.7 foot, but at different times along the three ranges reached an elevation -0.6 foot. The movements of the -0.6- and -0.7- and -0.8-foot contours along the three ranges (Fig. 25) show that lateral variations are quite small.

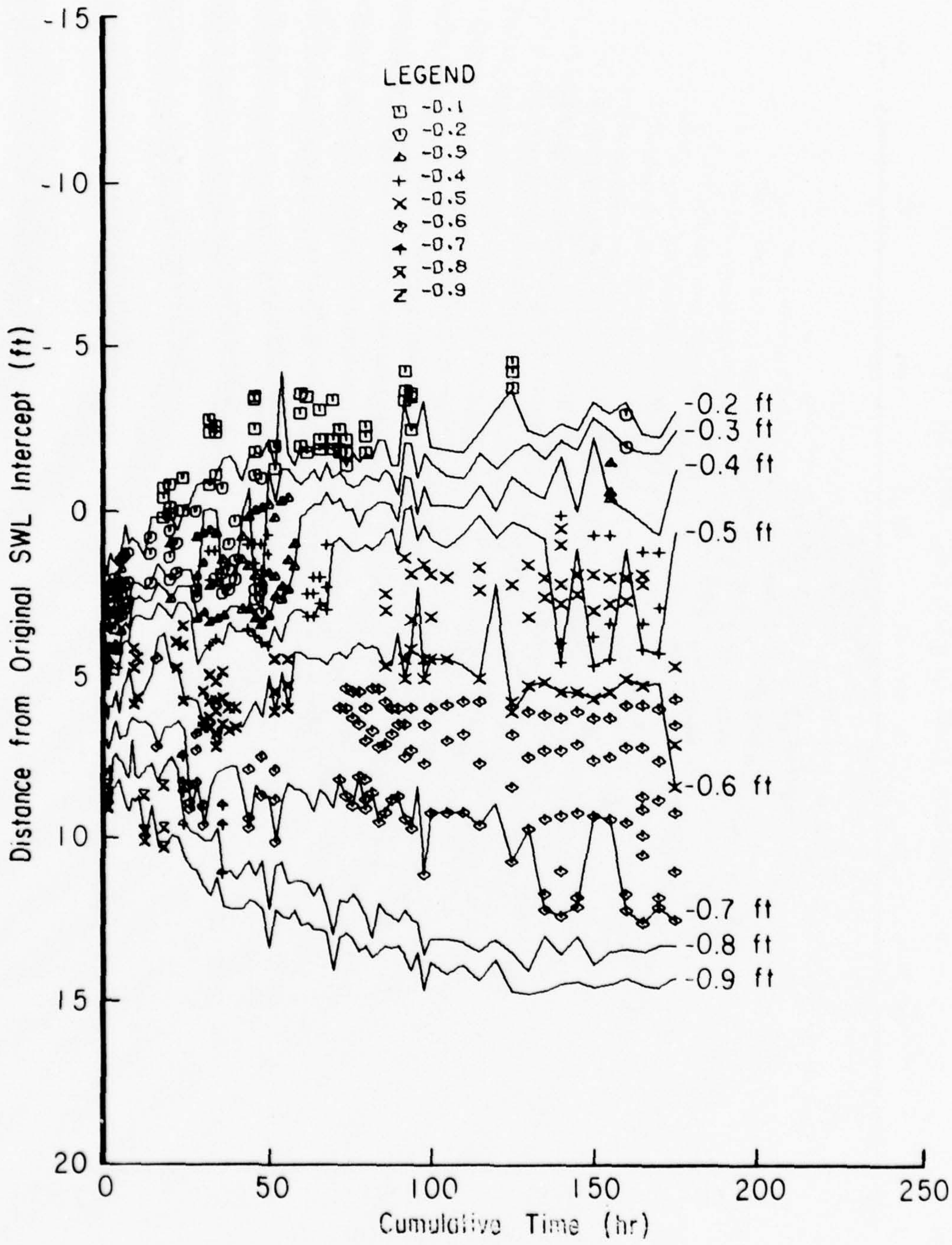

Figure 22. Changes in the inshore zone along range 1, experiment 70X-06.

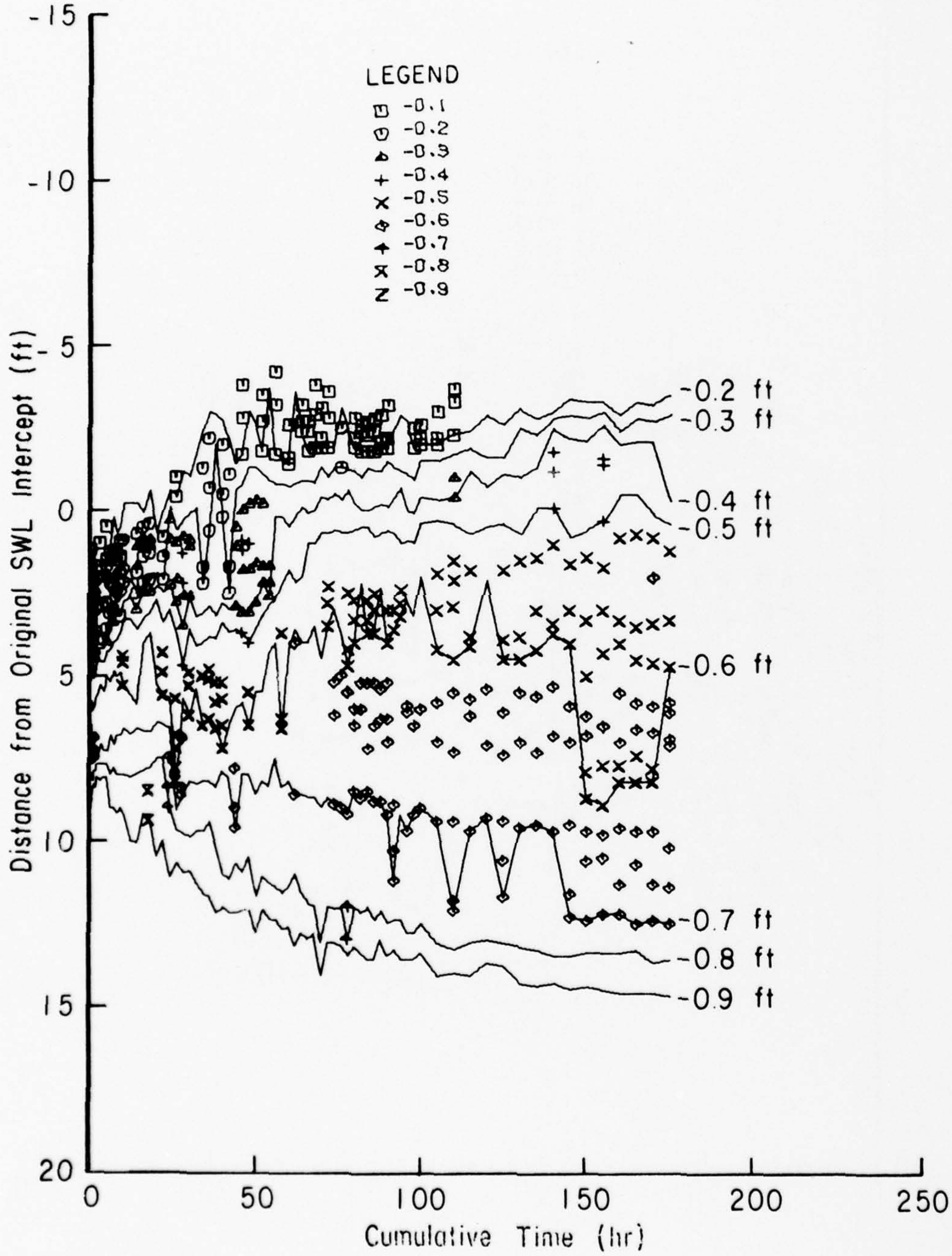

Figure 23. Changes in the inshore zone along range 3, experiment 70X-06.

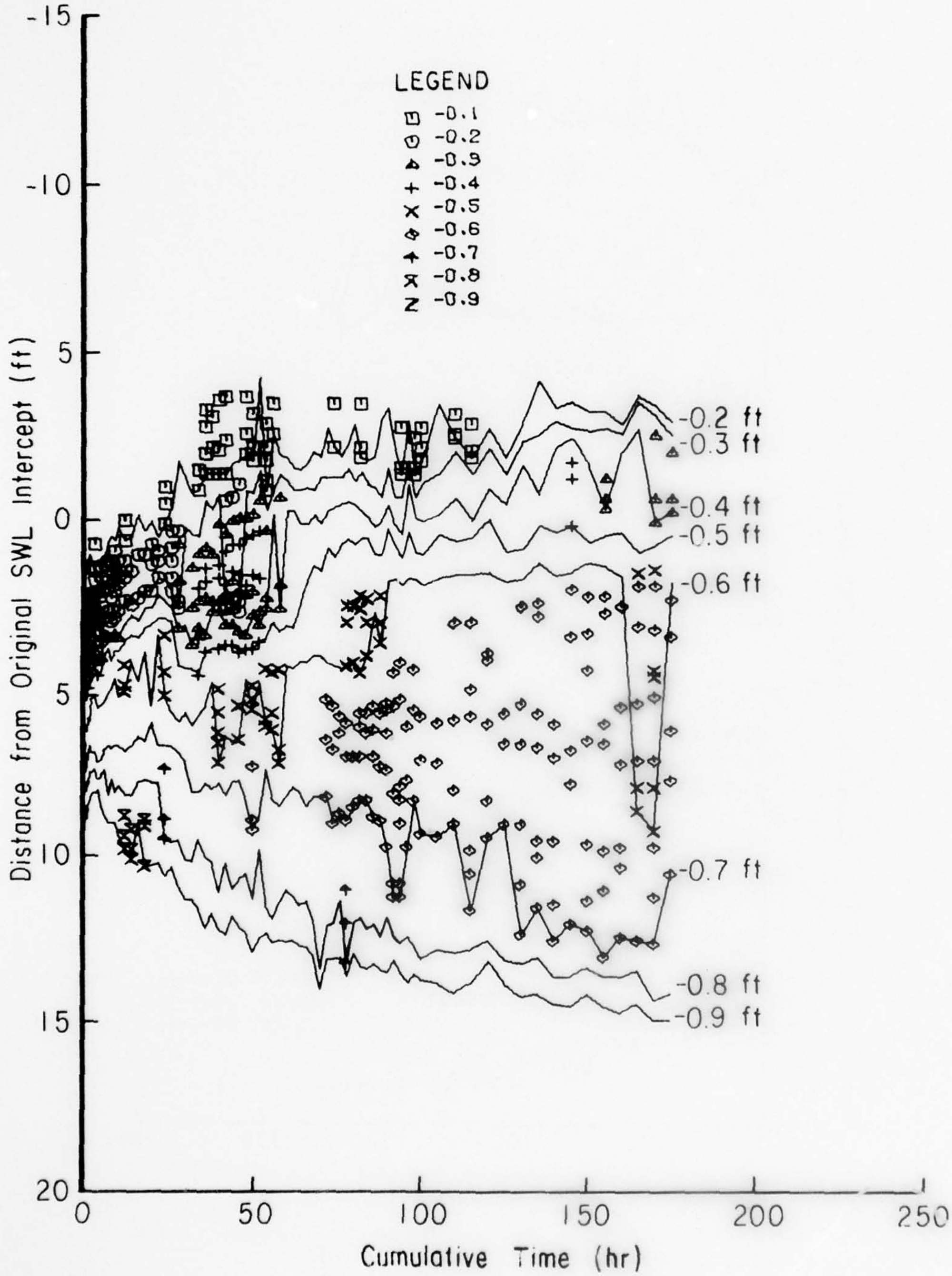

Figure 24. Changes in the inshore zone along range 5, experiment 70X-06.

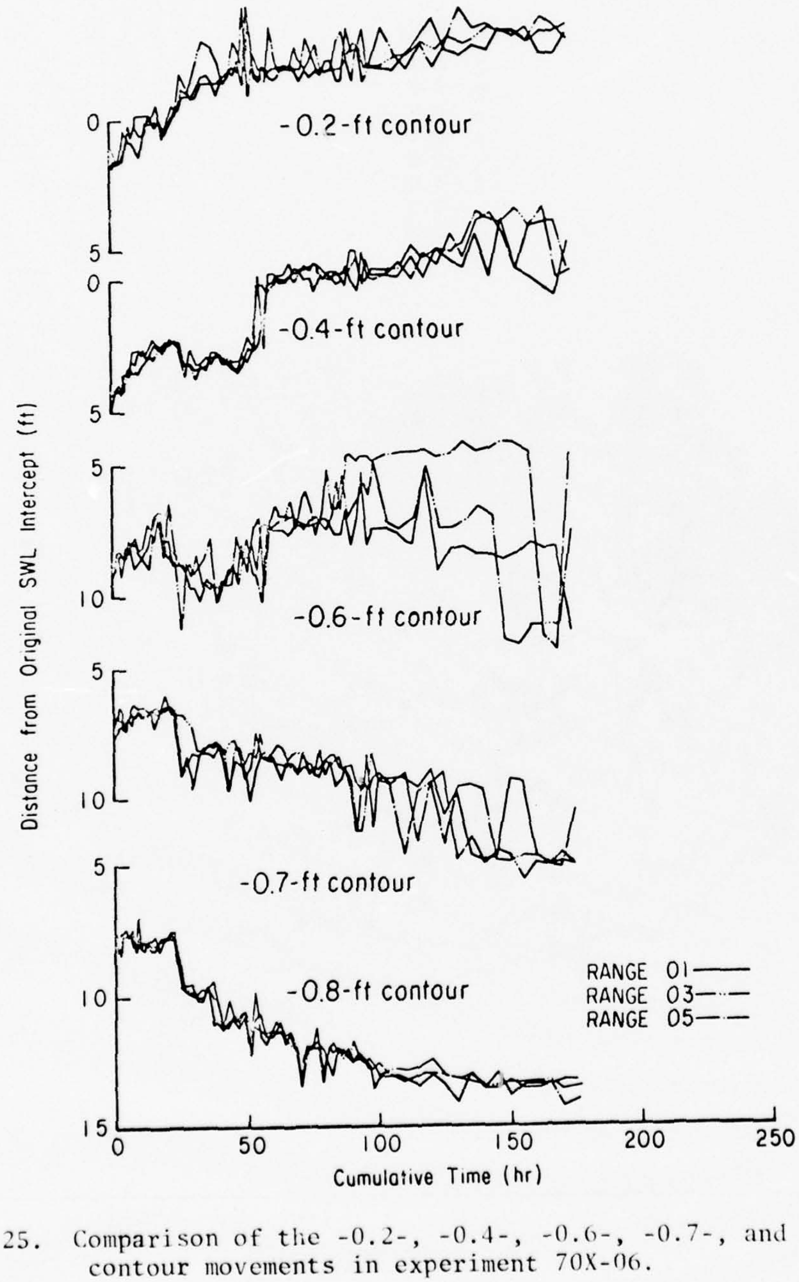

Figure 25. Comparison of the -0.2-, -0.4-, -0.6-, -0.7-, and -0.8-foot contour movements in experiment 70X-06.

(c) Inner Region (Experiment 70X-10). The inshore zone in the 10-foot tank developed in a pattern similar to that in the 6-foot tank, but at a different rate of change. Contour movement in the inshore along the five ranges for experiment 70X-10 is shown in Figures 26 to 30; the movement of selected individual depths along the five ranges is compared in Figure 31.

Within the first 10 minutes of testing a longshore bar formed at station 4 by plunging breakers. After 10 hours the bar position stabilized at station 3, with the elevation of the crest varying from -0.3 to -0.4 foot, as shown by the shifting of the -0.3-foot contour (see Figs. 26 to 30). At 56 hours the bar began to disappear and was completely eroded by 90 hours, as evidenced by the movement of the -0.4-foot contour intercepts in the figures.

Between 70 and 94 hours the inner inshore region was eroded, and from 94 to 160 hours this region had a fairly stable slope. After 160 hours the inner inshore along ranges 1 and 3 steepened (Figs. 26 and 27) and along ranges 5, 7, and 9 was stable (Figs. 28, 29, and 30).

The movement of the seawardmost contour intercepts for -0.2 and -0.4 foot is compared in Figure 31. The lateral variation in changes of the inner inshore is exhibited particularly at the 0.4-foot depth. The erosion of the bar began sooner along ranges 1 and 3 than along range 5, and much later along ranges 7 and 9.

(d) Outer Region (Experiment 70X-10). During the first 14 hours of testing little significant change occurred in the outer region, only slight erosion at 0.5- and 0.6-foot depths as a result of formation of the bar in the inner region. After 14 hours the -0.8-foot contour began moving seaward as a result of the deposition offshore. After 36 hours the -0.5-foot contour moved shoreward as the inner inshore was eroded. From 56 to 94 hours the shorewardmost -0.6-foot contours (see Figs. 26 to 30) moved shoreward creating the wide outer region. There was no significant lateral variation in the movement of the seaward edge of the outer region (-0.8-foot contours in Fig. 31). However, a significant lateral variation occurred in the depth of the outer region. The movements of the -0.6- and -0.7-foot contours (Fig. 31) partially indicate the variation--the depth over this shelf increased from range 1 to range 9. The depths along range 1 (Fig. 26) varied between 0.6 and 0.7 foot, along range 3 (Fig. 27) was generally 0.7 foot and occasionally 0.6 foot, along range 5 (Fig. 28) was 0.7 to 0.8 foot (twice reached a depth of 0.6 foot), along range 7 (Fig. 29) varied between 0.7 and 0.8 foot, and along range 9 (Fig. 30) varied between 0.7 and 0.9 foot.

(3) Offshore Zone. The offshore zone was essentially a zone of deposition. Initially, the deposited material formed a steeper slope in this zone and later the zone prograded seaward as more material was deposited.

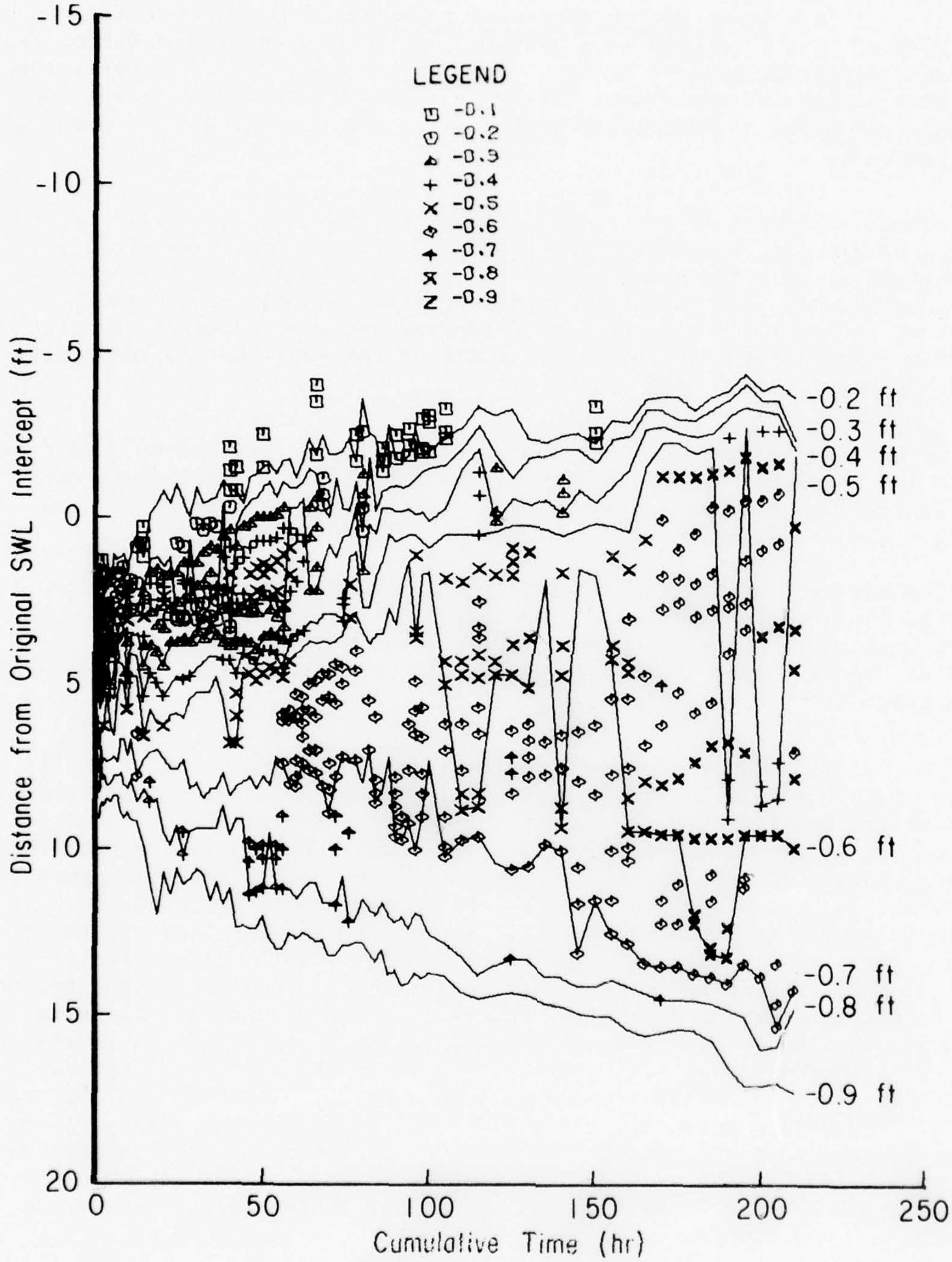

Figure 26. Changes in the inshore zone along range 1, experiment 70X-10.

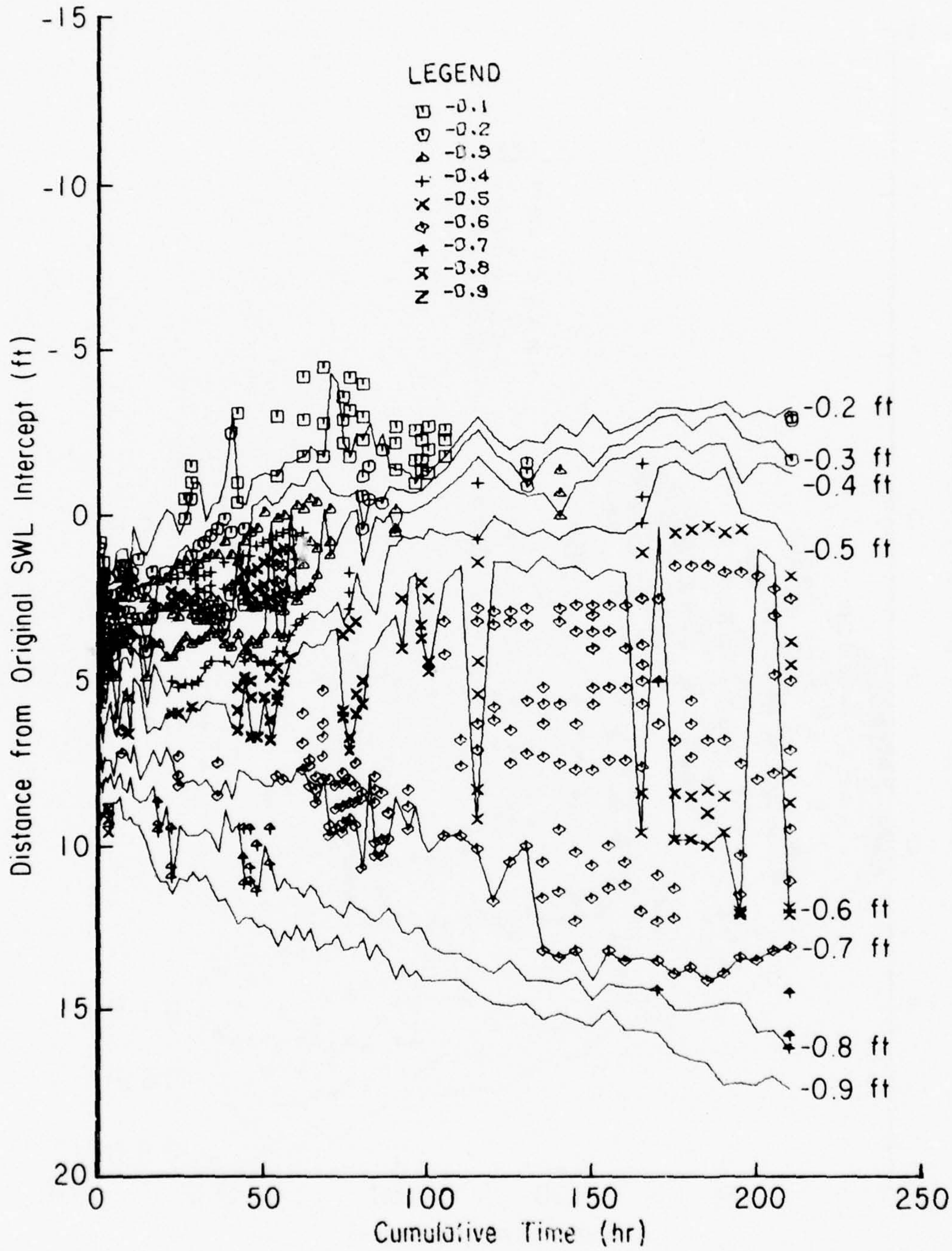

Figure 27. Changes in the inshore zone along range 3, experiment 70X-10.

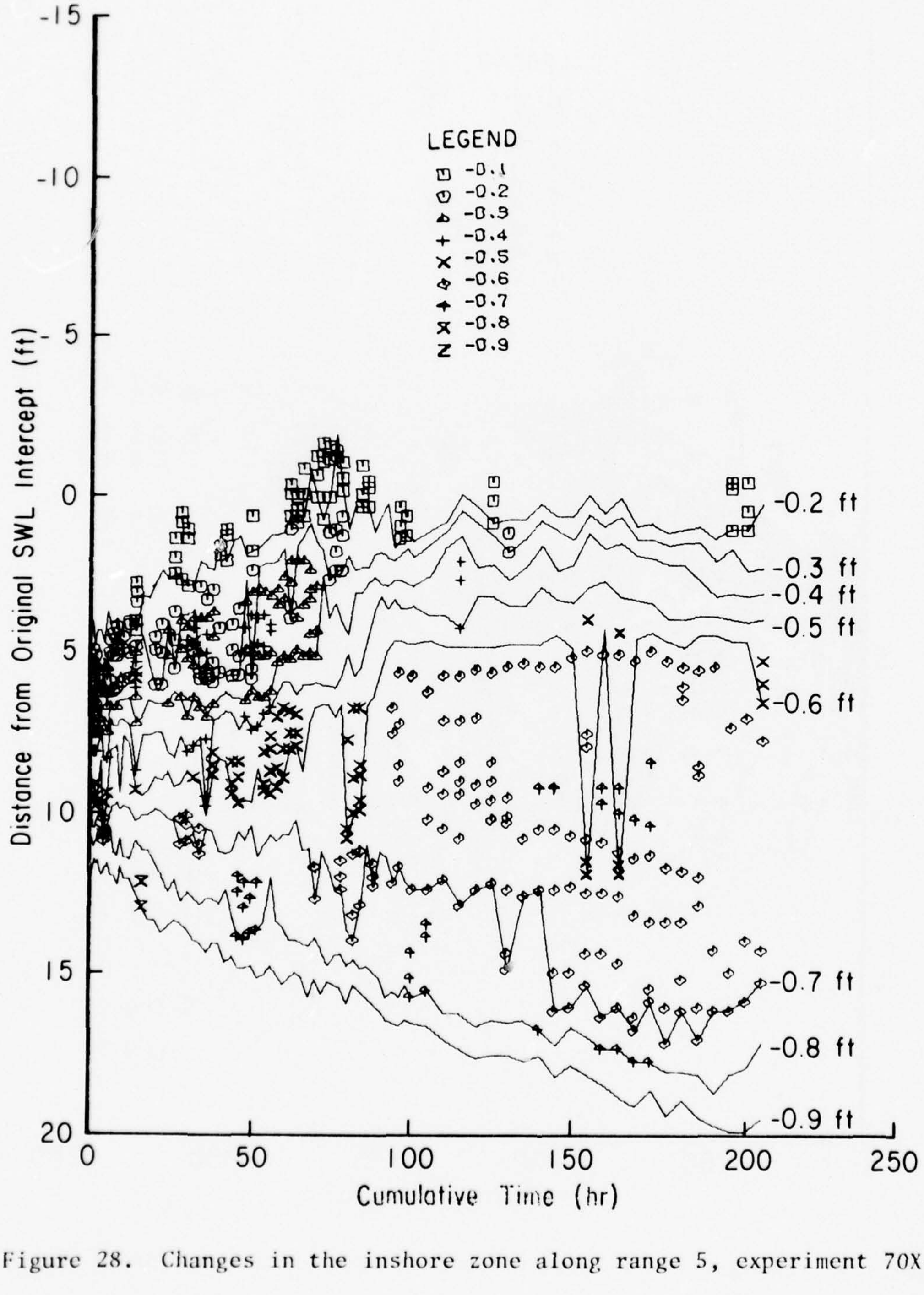

Figure 28. Changes in the inshore zone along range 5, experiment 70X-10.

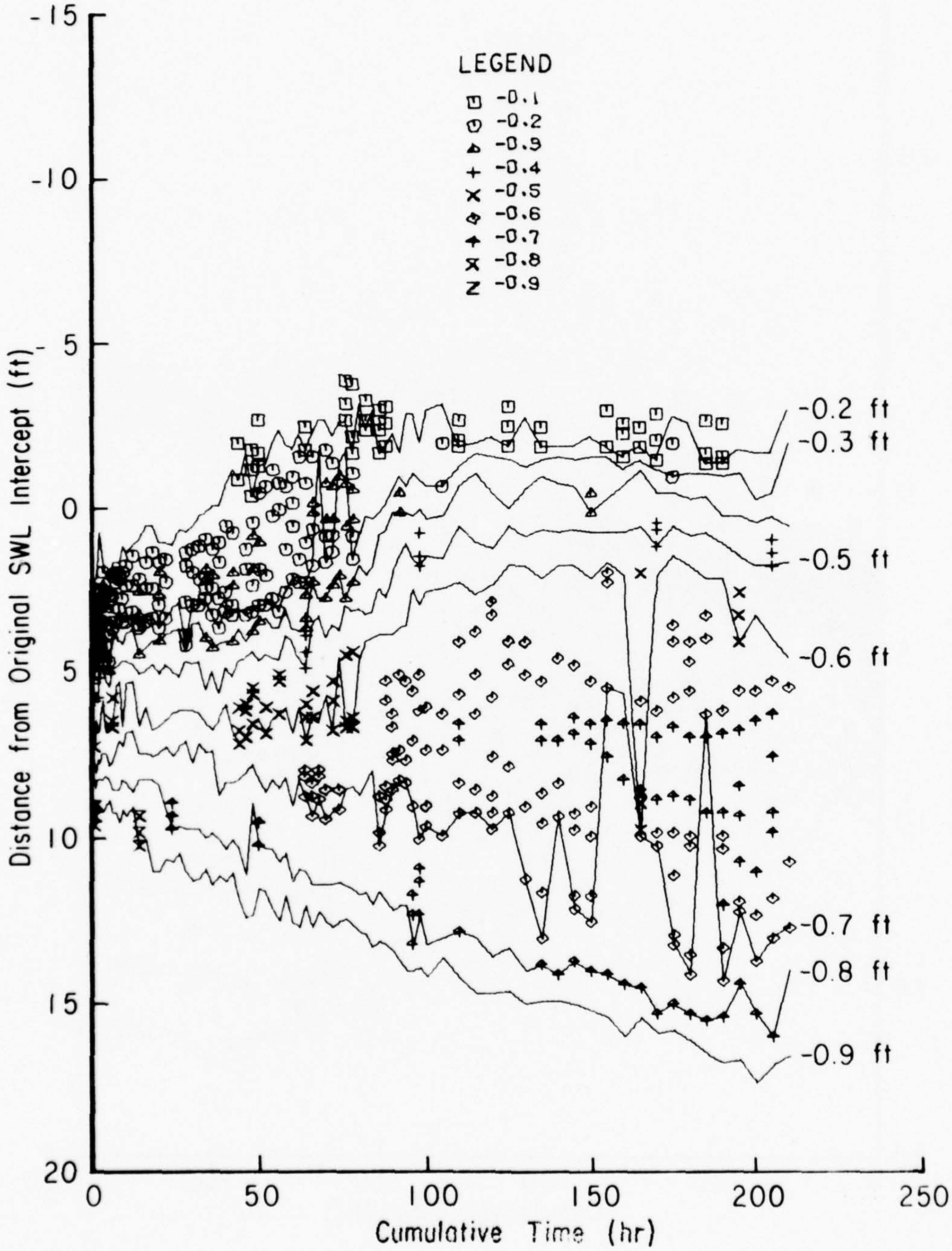

Figure 29. Changes in the inshore zone along range 7, experiment 70X-10.

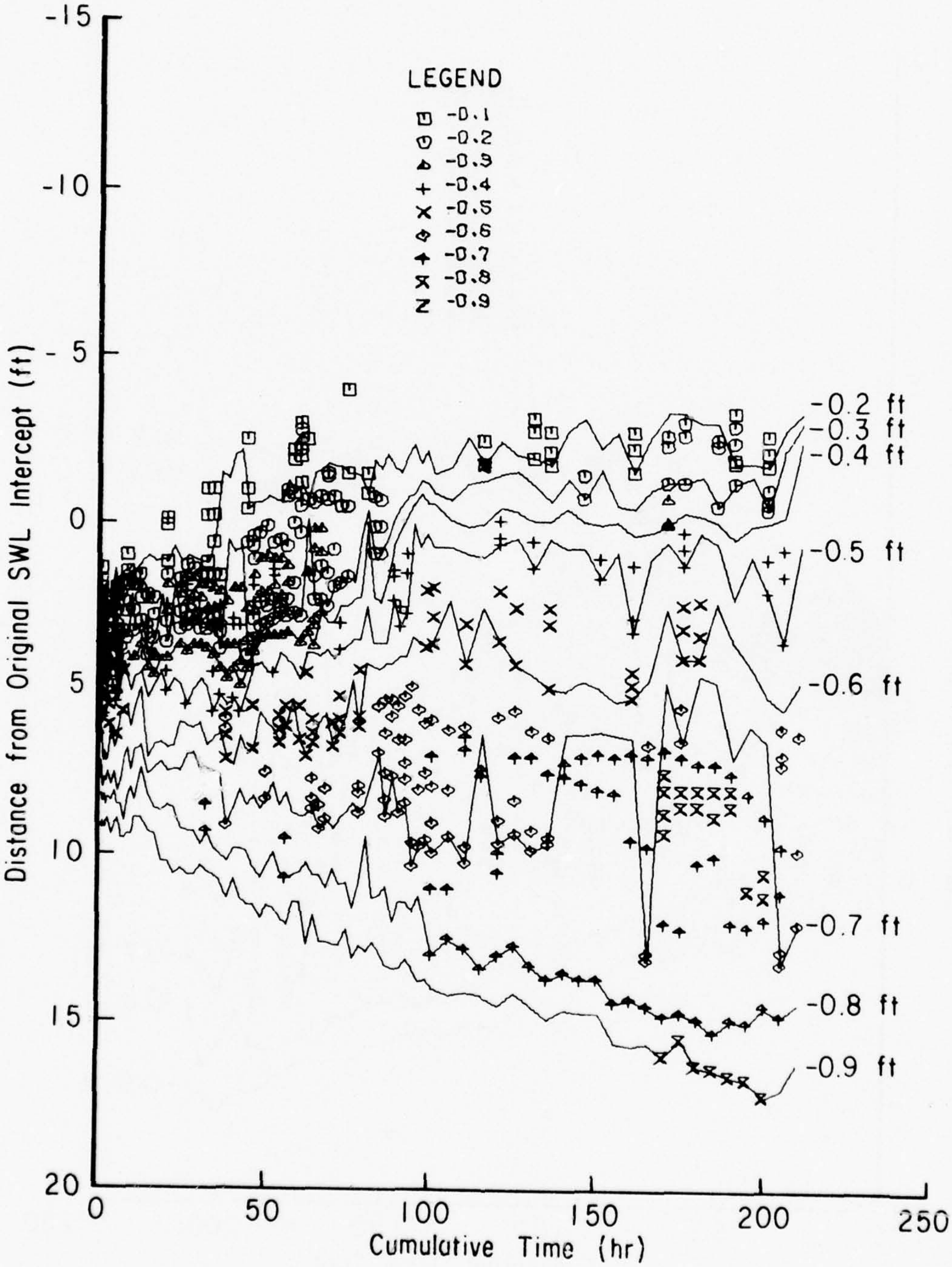

Figure 30. Changes in the inshore zone along range 9, experiment 70X-10.

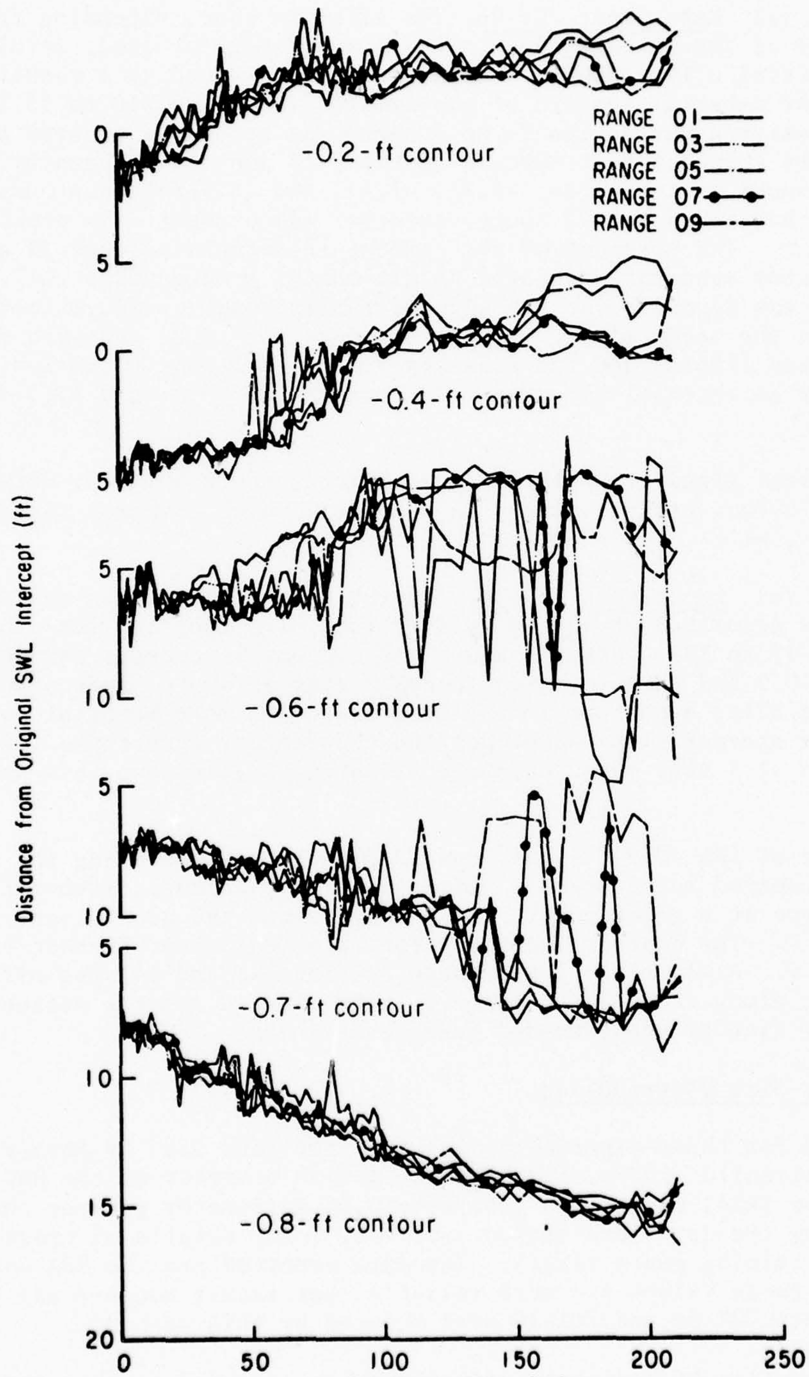

Figure 31. Comparison of the -0.2-, -0.4-, -0.6-, -0.7-, and -0.8-foot contour movements in experiment 70X-10.

(a) Experiment 70X-06. The offshore zone, extending from the seaward edge of the inshore zone to the seaward edge of sand, developed from the initial 0.10 slope to a relatively steep slope as a result of the deposition of material seaward of the breaker (see Figs. 10 to 13). The initial deposition during the first 5 hours was at depths greater than 1.1 feet and less than 1.6 feet between stations 11 and 16 as shown by the seaward movement of the -1.2-, -1.3-, -1.4-, and -1.5-foot contours (Figs. 10 to 13). Between 5 and 22 hours, material was deposited at depths greater than 0.8 foot. The movement of the contour intercepts between 24 and 100 hours indicates sand was deposited at all depths greater than -0.7-foot and as sand was deposited at the edge of the inshore zone (0.8-foot depth) it slid down the steep slope. After 100 hours the -0.8- and -0.9-foot contours moved little, and the area seaward of -1.1-foot elevation became even steeper as material was deposited between the -0.9- and -1.1-foot elevations.

No apparent significant lateral variations occurred in the offshore zone of the 6-foot tank, as shown in Figure 32 which compares movements of the -0.9-, -1.3-, and -2.0-foot contours.

(b) Experiment 70X-10. During the first 5 hours most of the sediment was deposited at depths greater than -1.0 foot and less than -1.5 feet (Figs. 13 to 17). After 5 hours the contour intercepts for depths of -1.0, then -0.9, and then -0.8 foot began moving offshore, indicating that material was being deposited in the same area. As more material moved into this area, a steeper slope developed and the contour intercepts for depths greater than -1.4 feet moved offshore as material slid down this steep face.

Movement of the -0.9-, -1.3-, and -2.0-foot contours along the five ranges is compared in Figure 33. After the first 5 hours, material was moved offshore at a greater rate along range 1 and and at a slower rate along range 9. The contour intercept for -2.0 feet moved farther offshore along range 9. Along range 1 and range 3 (Figs. 13 and 14) the offshore was steeper; along range 7 and range 9 (Figs. 16 and 17) the offshore zone was slightly flatter and extended farther offshore.

3. Sediment-Size Distribution.

The sand for these experiments was the same sand used by Savage (1959, 1962) and Fairchild (1970a, 1970b). The median diameter of the Rapid Sediment Analyzer (RSA) method was generally 0.04 millimeter greater than that determined by the dry sieve method (see Vol. I for details of procedures used in determining grain sizes). The data reported are the RSA values, not because these values are more reliable, but rather because all the data in experiments 70X-06 and 70X-10 were reduced by this method.

The collection of sediment samples was not included in the experimental program until near the end of the 1970 experiments. As a result, no data on the actual initial grain-size distribution exist. The RSA median grain size of the sediment used, when well mixed at the beginning of the 1971

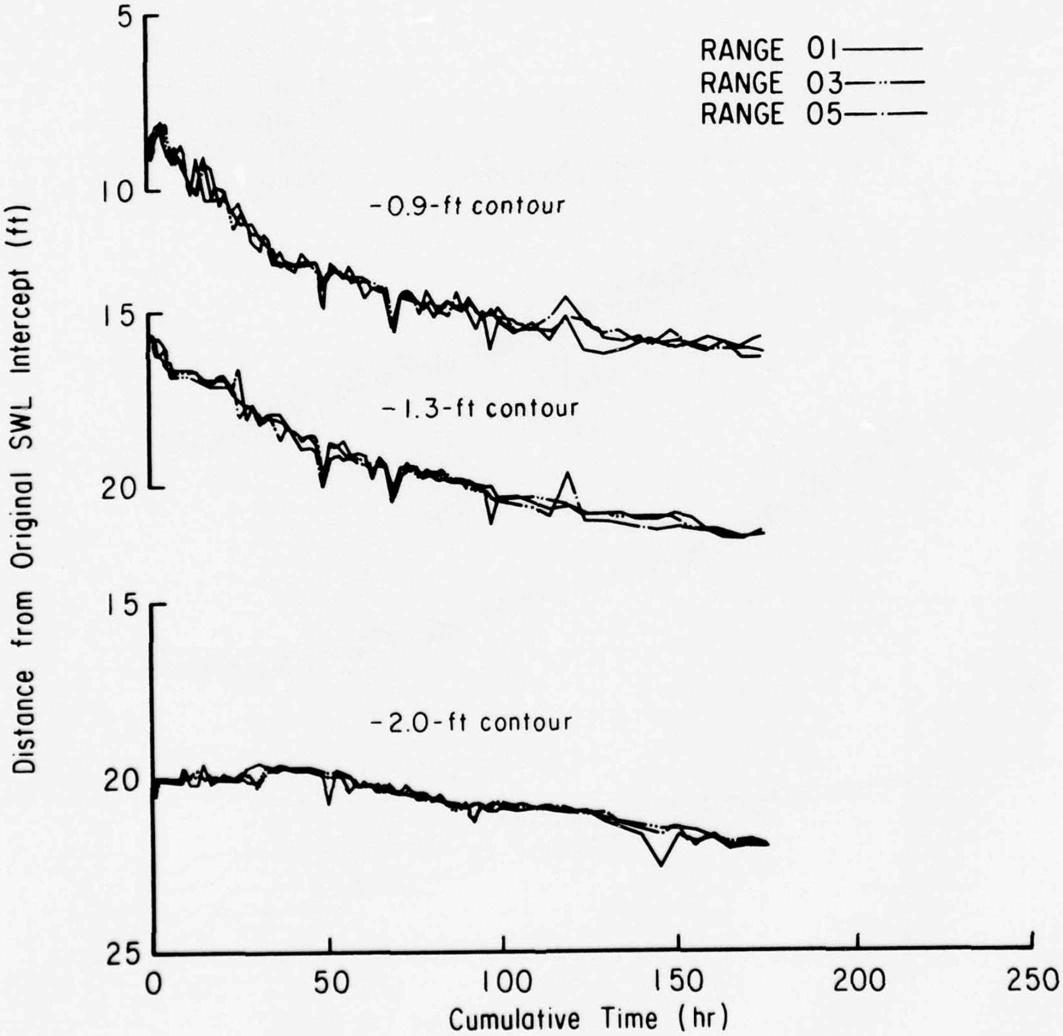

Figure 32. Comparison of the -0.9-, -1.3-, and -2.0-foot contour movements in experiment 70X-06.

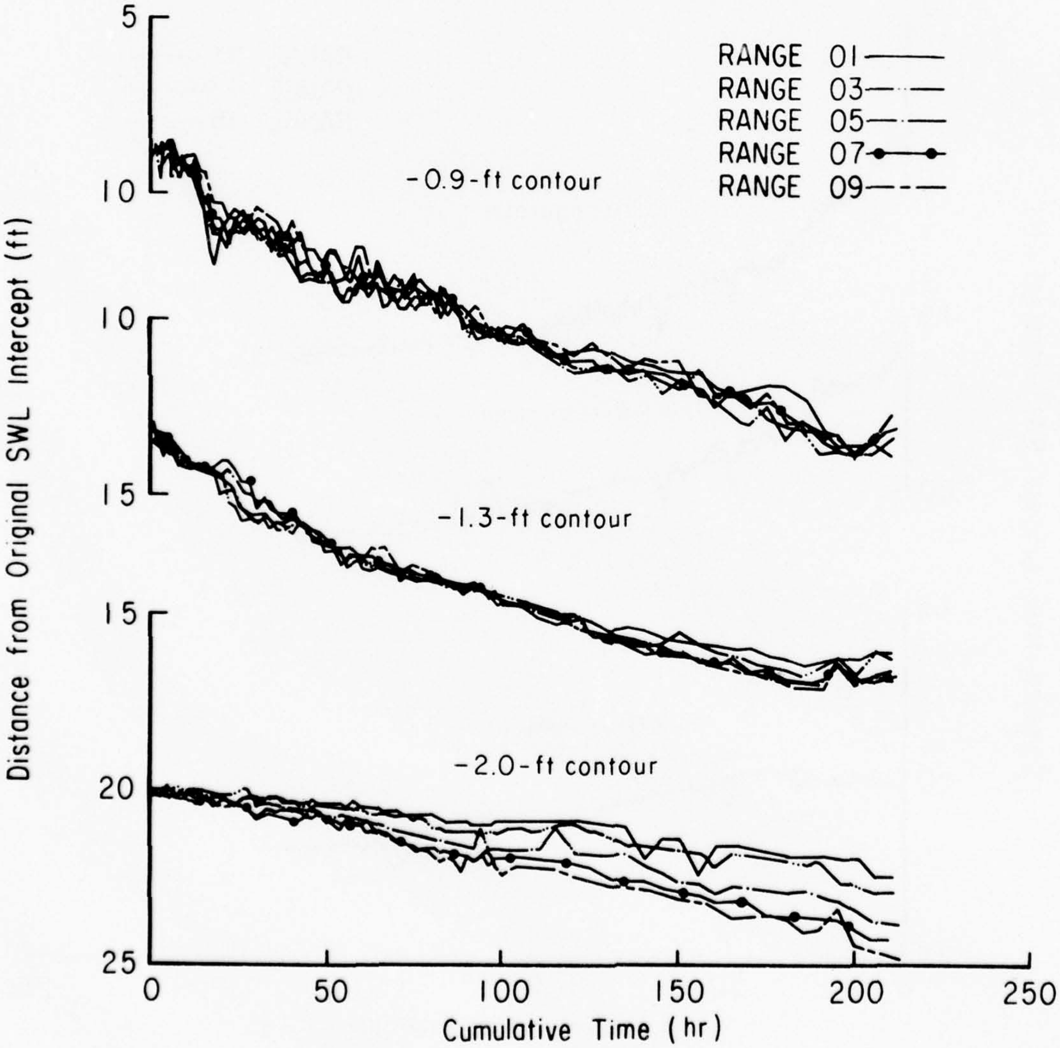

Figure 33. Comparison of the -0.9-, -1.3-, and -2.0-foot contour movements in experiment 70X-10.

experiments, was 0.27 millimeter (1.92 phi) (see Vol. I). Some gravel was removed from the sediment before the 1971 experiments. Therefore, the initial sediment-size distribution for the 1970 experiments was greater than 0.27 millimeter by an unknown amount.

Data from experiment 70X-06 at 150 hours and from experiment 70X-10 at 200 hours are given in Table 11. The median grain size on the foreshore was generally 0.35 millimeter. At the toe of the foreshore (elevation≈ -0.2 foot), the median grain size was 0.38 millimeter or greater. The median grain size decreased in the offshore direction to 0.22 millimeter in the offshore zone.

4. Breaker Characteristics.

a. Breaker Position with Time and Depth. Data collection and reduction procedures for breaker characteristics are discussed in the Appendix. A plot of breaker position superimposed on a plot of contour movement along range 3 for experiment 70X-06 is shown in Figure 34. During the initial 32 hours of testing the wave broke at a depth of approximately 0.5 foot (between stations 3.5 and 5.0). From 32 to 42 hours the breaker position moved from station 4.0 to 6.5. This shift in breaker position occurred after the shelf in the outer region of the inshore zone began to develop. From 42 to 78 hours the breaker position continued to move offshore as the seaward edge of the inshore zone moved seaward. From 98 hours until the end of the test the wave broke at a depth of 0.7 foot.

A similar plot of breaker position superimposed on a plot of contour movement with time for experiment 70X-10 is shown in Figure 35. During the first 40 hours the wave broke between stations 4.0 and 5.5, at a depth of 0.4 to 0.5 foot. Up to 12 hours the wave broke uniformly across the tank; after 12 hours the wave broke first along range 1. After 40 hours the breaker position gradually moved seaward as the outer edge of the inshore zone moved seaward. The inshore zone formed more gradually in the 10-foot tank and there were no rapid changes in the breaker position. From 40 to 86 hours the wave broke at a depth of 0.6 foot and after 86 hours at a depth of 0.7 foot. However, the important distinction is that the breaker position did not occur at the seawardmost position of the -0.7-foot contour intercept as in the 6-foot tank.

b. Breaker Type with Position, Time, and Depth. Up to 40 hours the breaker in experiment 70X-06 was a plunging-type breaker. Between 40 and 45 hours the breaker type changed from plunging to spilling and then remained a spilling-type breaker until the end of the experiment. The change in breaker type occurred as the breaker position moved offshore to a depth of 0.6 foot. Similarly, in experiment 70X-10, the breaker type changed from plunging to spilling as the breaker position moved to a depth of 0.6 foot.

5. Water Temperature.

Figure 36 gives data on daily average water temperature versus time for experiments 70X-06 and 70X-10. Since water temperature was not

Table 11. Sediment-size analysis by RSA method for experiments 70X-06 and 70X-10.

Position (ft)	Range 1			Range 3			Range 5			Range 7			Range 9		
	Depth (ft)	Median (mm)	Median (phi)	Depth (ft)	Median (mm)	Median (phi)	Depth (ft)	Median (mm)	Median (phi)	Depth (ft)	Median (mm)	Median (phi)	Depth (ft)	Median (mm)	Median (phi)
Experiment 70X-06 at 150 hr															
-6.0	0.30	0.33	1.60	0.30	0.36	1.49	0.30	0.34	1.55						
-4.0	-0.10	0.42	1.24	----	----	----	----	----	----						
-3.5	-0.15[1]	0.57	0.82	-0.20	0.39	1.35	-0.15	0.38	1.40						
-2.0	-0.40	0.31	1.69	-0.50	0.31	1.67	-----	----	----						
0.0	-0.43	0.32	1.63	-0.50	0.32	1.65	-0.48	0.33	1.61						
2.0	------	----	----	-0.60	0.27	1.91	-----	----	----						
2.2	-0.60	0.29	1.76	-----	----	----	-----	----	----						
3.0	-----	----	----	-----	----	----	-0.61[2]	0.30	1.73						
4.3	-0.50	0.31	1.69	-----	----	----	-----	----	----						
6.0	-----	----	----	-0.60	0.27	1.90	-0.64	0.29	1.78						
6.7	-0.70	0.27	1.87	-----	----	----	-----	----	----						
10.0	-0.71	0.27	1.91	-0.70	0.26	1.93	-0.68	0.27	1.89						
13.0	-0.78	0.29	1.80	-0.72	0.28	1.83	-0.74	0.28	1.85						
16.0	-1.02	0.26	1.96	-1.03	0.25	1.99	-1.03	0.26	1.96						
19.0	-1.50	0.25	1.99	-1.45	0.25	2.01	-1.25	0.25	2.03						
20.5	-1.84	0.22	2.18	-1.50	0.25	1.97	-1.90	0.23	2.10						
21.0	-1.85	0.25	2.00	-----	----	----	-----	----	----						
23.0	-2.20	0.25	2.01	-2.20	0.25	1.98	-2.20	0.25	2.03						
26.0	-----	----	----	-2.20	0.29	1.77	-----	----	----						
Experiment 70X-10 at 200 hr															
-6.0	0.2	0.30	1.73	0.2	0.35	1.51	0.3	0.35	1.50	0.3	0.36	1.47	0.2	0.40	1.32
-5.0	-----	----	----	-----	----	----	-----	----	----	----	----	----	----	----	----
-4.5	-----	----	----	-----	----	----	-----	----	----	----	----	----	----	----	----
-4.3	-0.2	0.67	0.58	-----	----	----	-----	----	----	----	----	----	----	----	----
-4.0	-----	----	----	-0.1	0.51	0.98	-----	----	----	0.0	0.52	0.95	-0.1	0.46	1.11
-3.5	-0.4	0.39	1.35	-----	---	----	-0.2	0.50	1.01	----	----	----	----	----	----
-3.0	-----	----	----	-0.2	0.38	1.40	-0.2	0.43	1.23	----	----	----	-0.2	0.42	1.24
-2.0	-0.6[3]	0.29	1.79	-0.3	0.48	1.05	-0.2	0.39	1.37	----	----	----	-0.2	0.42	1.26
-1.5	-----	----	----	-----	----	----	-----	----	----	-0.1	0.41	1.29	----	----	----
-1.0	-0.5	0.34	1.56	-----	----	----	-----	----	----	----	----	----	----	----	----
0.0	-0.5	0.29	1.81	-0.5	0.34	1.57	-0.4	0.40	1.33	-0.4	0.33	1.61	----	----	----
2.5	-0.5	0.28	1.83	-----	----	----	-----	----	----	----	----	----	-0.5	0.36	1.47
5.0	-0.6	0.32	1.65	-0.6	0.27	1.87	-0.7	0.31	1.67	-0.7	0.32	1.63	-0.6	0.29	1.78
6.0	-----	----	----	-0.6	0.29	1.81	-----	----	----	----	----	----	----	----	----
7.0	-----	----	----	-----	----	----	-0.8	0.27	1.89	----	----	----	----	----	----
10.0	-0.6	0.29	1.79	-0.7	0.28	1.82	-0.7	0.28	1.86	-0.8	0.28	1.82	-0.9	0.28	1.86
15.0	-0.8	0.26	1.94	-0.8	0.27	1.91	-0.8	0.28	1.85	-0.8	0.28	1.83	-0.8	0.28	1.85
20.0	-1.4	0.25	1.98	-1.3	0.26	1.96	-1.3	0.25	2.02	-1.3	0.26	1.97	-1.3	0.25	2.00
21.0	-1.6[4]	0.25	2.03	-----	----	----	-----	----	----	----	----	----	----	----	----
22.0	-1.9	0.24	2.04	-----	----	----	-----	----	----	----	----	----	----	----	----
22.5	-----	----	----	-1.9	0.25	2.01	-1.8	0.25	1.98	-1.7	0.26	1.97	-1.6	0.25	2.02
25.0	-2.2	0.30	1.73	-2.2	0.26	1.93	-----	----	----	-2.2	0.25	1.98	-2.2	0.24	2.05
27.5	-----	----	----	-----	----	----	-----	----	----	----	----	----	-2.2	0.25	1.98

[1]Range 2.
[2]Range 6.
[3]Range 0.25.
[4]Range 1.5.

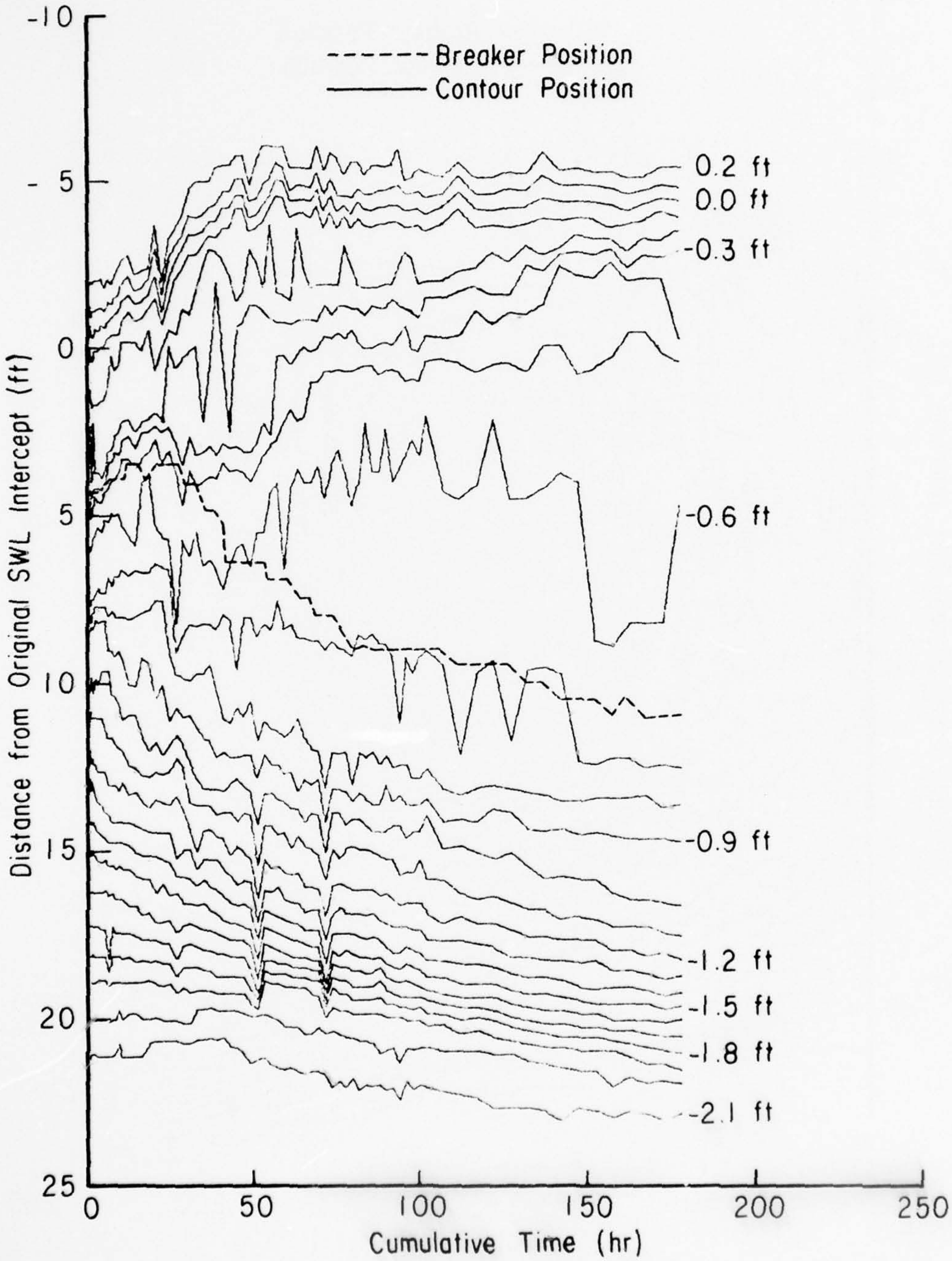

Figure 34. Movement of the breaker position in experiment 70X-06.

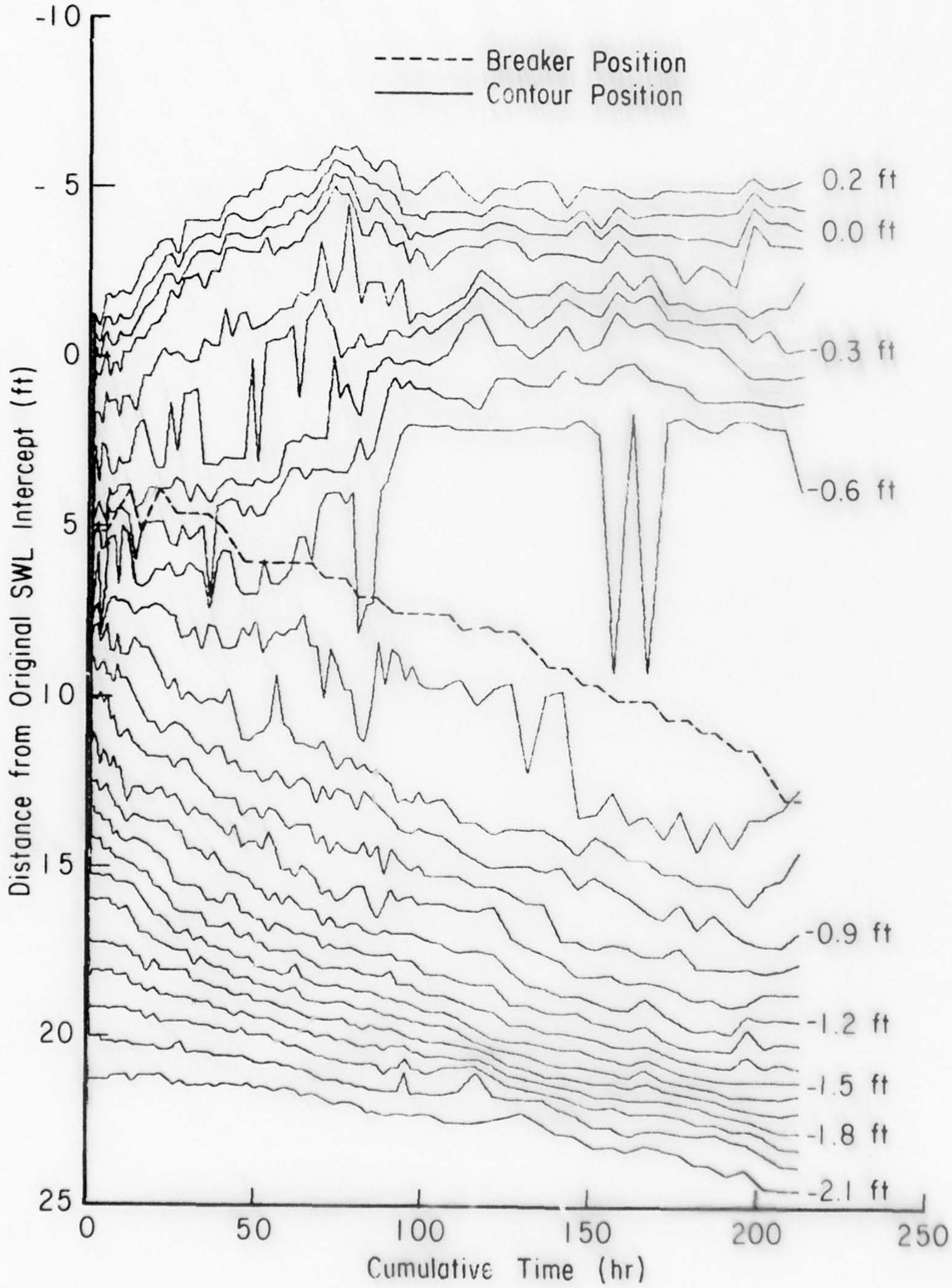

Figure 35. Movement of the breaker position in experiment 70X-10.

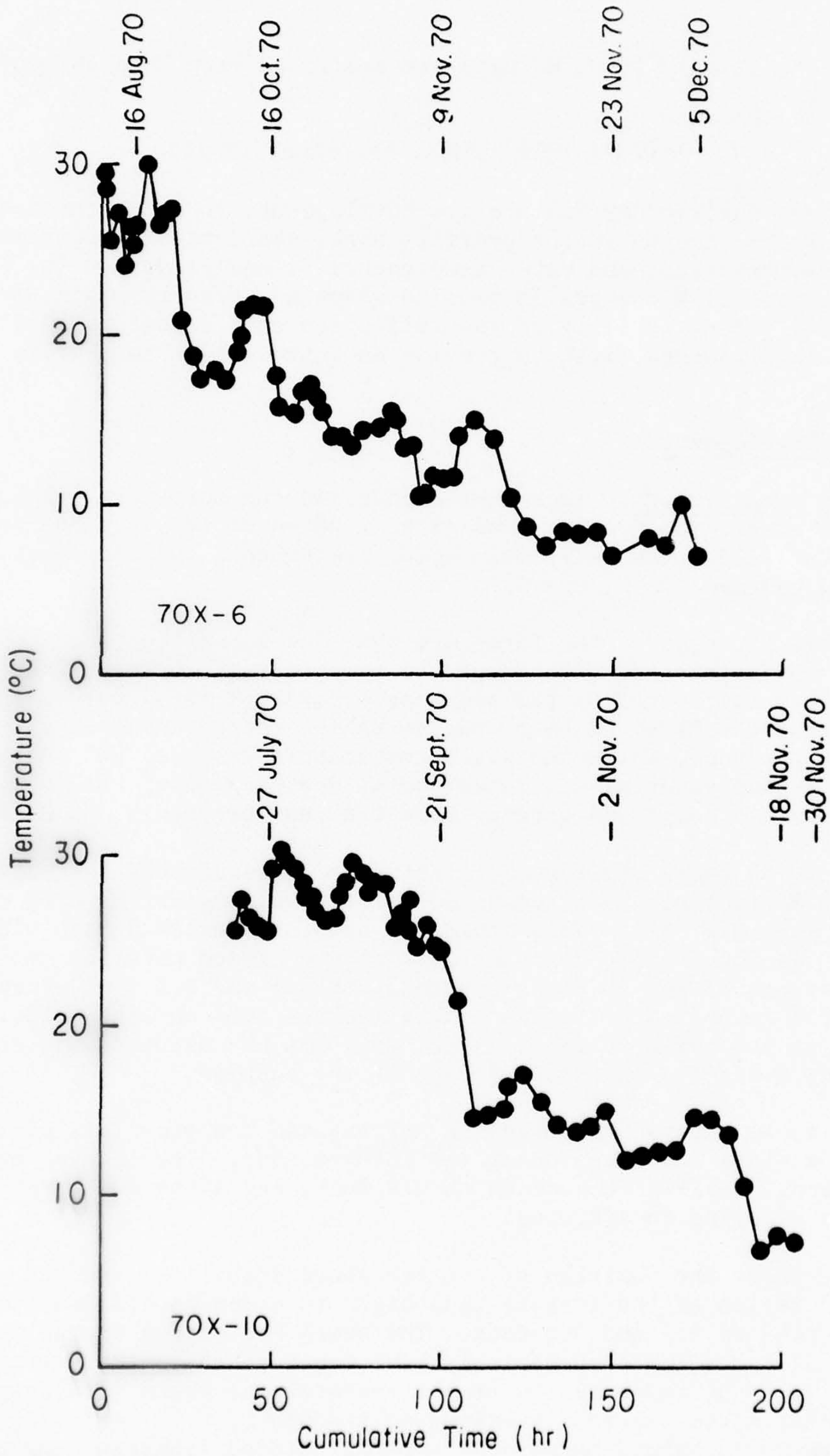

Figure 36. Daily mean water temperatures in experiments 70X-06 and 70X-10.

measured before 13 July 1970, no data are available from 0 to 38 hours in experiment 70X-10.

III. PROFILE DEVELOPMENT AND REFLECTIVITY

Results are analyzed by (a) profile development, in which the interdependence of the changes in the profile shape, sediment-size distribution, breaker characteristics, and water temperature is analyzed; and (b) profile reflectivity, in which changes in profile shape and breaker characteristics are related to the variability of the reflection coefficient. Profile development is discussed first to provide an introduction to profile reflectivity.

1. Profile Development.

a. Experiment 70X-06. Important changes in the foreshore, inshore, and offshore zones, the breaker conditions, and water temperatures are summarized in Table 12. The daily mean water temperature and the shoreline position are compared in Figure 37.

During the first hour, the foreshore zone developed the basic shape which was maintained throughout the remainder of the experiment, and a longshore bar was formed by the plunging breaker in the inner inshore region. During the first 22 hours the foreshore retreated at an average of 0.06 foot per hour, while the water temperature was near 28° Celsius. Most of the eroded material was deposited at depths greater than 1.1 feet during the first 5 hours and greater than 0.8 foot between 5 and 22 hours.

From 22 to 30 hours the foreshore retreated considerably faster (an average of 0.14 foot per hour) coincidental with a temperature drop of 10° Celsius (see Fig. 37). This increased erosion created a much wider inner region in the inshore zone and most of the eroded material was deposited between 22 and 26 hours at depths of 0.7 and 0.8 foot, forming the flat shelf in the outer region of the inshore zone and the relatively steep slope in the offshore zone. After 26 hours the material was deposited at a depth of 0.8 foot, the seaward edge of the inshore.

From 30 to 44 hours the shoreline retreat and the stability of the bar created a wider inner region of the inshore zone. The breaker began moving seaward, breaking at a depth of 0.6 foot, and after 40 hours, changed from plunging to spilling.

After 44 hours the position of the foreshore stabilized and the shelf in the outer region of the inshore zone began to widen as sediment was eroded at depths of 0.5 and 0.6 foot. The beach had eroded to the back of the tank at 54 hours and sand replenishment began at that time. After 54 hours the bar in the inner region of the inshore zone began to disappear, and the breaker moved seaward, breaking at a depth of 0.7 foot. The outer region continued to extend seaward as material eroded from the backshore was deposited on the steep offshore slope. After 66 hours the shape of the inner inshore became stable.

Table 12. Summary of profile development for experiment 70X-06.

Time (hr)	Foreshore	Inner inshore	Outer inshore	Offshore	Breaker conditions		Water temperature (°C)
					Depth (ft)	Type[1]	
0 to 1	developed characteristic shape	bar formed			0.5	P	28 to 30
1 to 5	avg. erosion rate of 0.06 ft/hr	elevation of bar increased to -0.3 ft		deposition > 1.1 ft	0.5	P	25 to 26
5 to 8		bar moved shoreward, depth 0.3 ft		deposition > 0.8 ft	0.5	P	24 to 27
8 to 22		bar stable (depth and position)		deposition > 0.8 ft	0.5	P	26 to 30
22 to 26	avg. erosion rate of 0.14 ft/hr	bar moved seaward, depth 0.4 ft	large deposition at depths of 0.7 and 0.8 ft	deposition at 0.9 ft	0.5	P	28; drop to 18
26 to 30		position of bar stable, depth varied 0.3 to 0.4 ft	deposition at 0.8 ft	large deposition at 1.1 and 1.0 ft	0.5	P	17 to 18
30 to 40	0.10			deposition at all depths	position moving seaward to 0.6-ft depth	P	17 to 20
40 to 44					0.6	changed from P to SP	21
44 to 54	SWL stable erosion of last of scarp		erosion at 0.5 and 0.6 ft		0.6	SP	21; drop to 16
54 to 66	fill started erosion of fill << avg.	bar eroded	erosion at 0.5 ft		position moving seaward to 0.7-ft depth	SP	14 to 18
66 to 90	erosion < avg.	stable slope	shoreward edge stabilized for remainder		0.7	SP	14 to 15; drop to 11
90 to 100	erosion >> avg.				0.7	SP	11
100 to 135	erosion = avg.		seaward edge stabilized for remainder	deposition > 0.9 ft	0.7	SP	11; rise to 15; drop to 8
135 to 140		erosion formed steeper slope	deposition at 0.6 and 0.7 ft		0.7	SP	8
140 to 175		stable slope	0.7-ft depth at seaward edge		0.7	SP	7 to 10; avg. 8
175 (median grain size in mm)	range 0.34 to 0.56 avg. 0.39	0.27 to 0.33 0.31	0.26 to 0.31 0.28	0.22 to 0.29 0.25			

[1]P = plunging; SP = spilling-plunging.

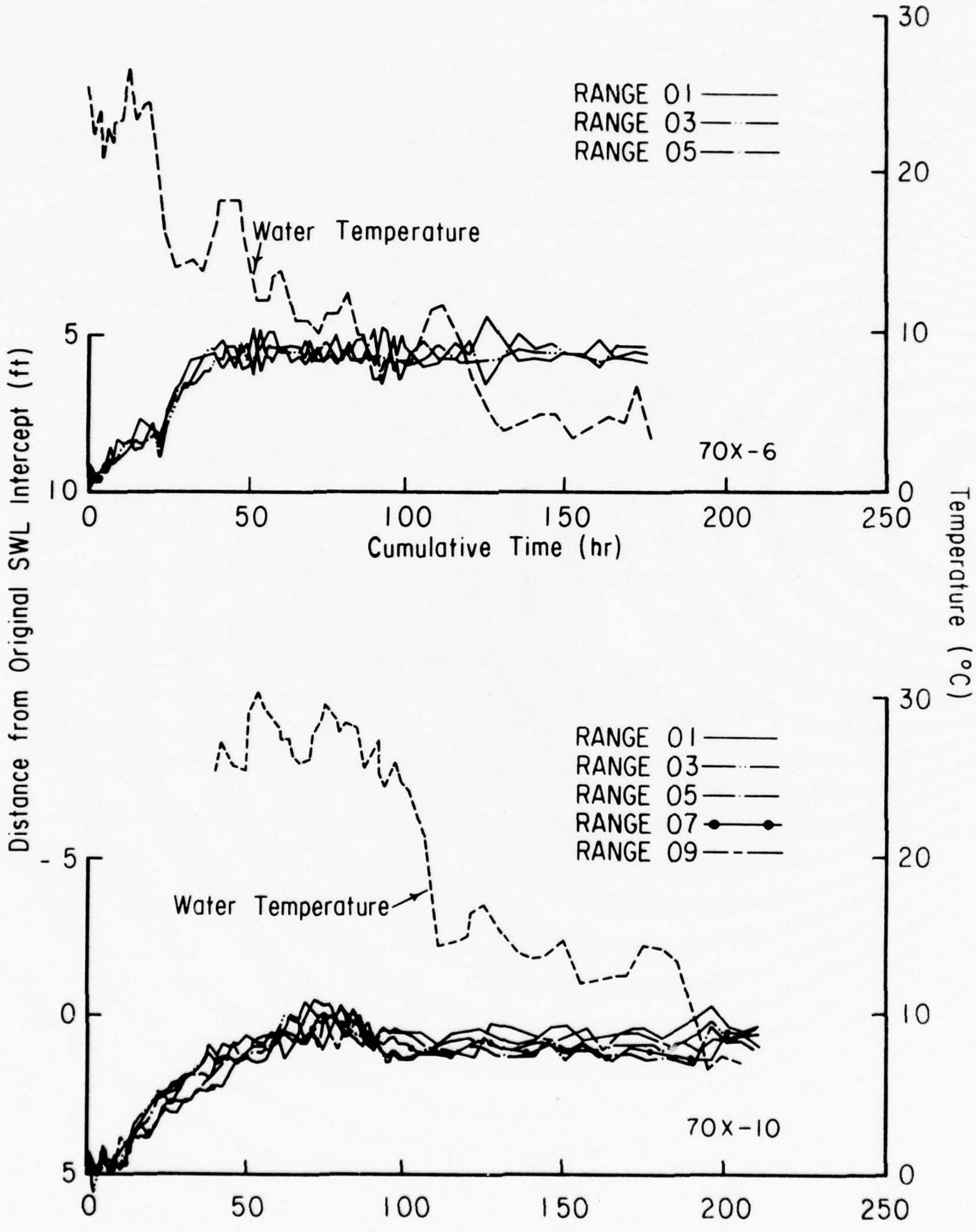

Figure 37. Comparison of daily mean water temperatures and shoreline positions in experiments 70X-06 and 70X-10.

After 100 hours the position of the outer edge of the inshore zone became stable and the material was deposited farther offshore in depths greater than 0.9 foot. After 135 hours the inner region of the inshore zone was again eroded, creating a steeper slope in this region, while the temperature dropped below 10° Celsius. The material was deposited at the outer edge of the inshore zone in depths of 0.6 and 0.7 foot.

The definite decrease in median grain size in the seaward direction indicates that the finer material was eroded from the nearshore and deposited offshore, as expected.

b. Experiment 70X-10. Important changes in the profile shape, breaker condition, and water temperature are summarized in Table 13. The daily mean water temperature and the shoreline position are compared in Figure 37.

During the first 10 hours the foreshore retreated at an average rate of 0.05 foot per hour. As the foreshore retreated, a bar was formed in the inner inshore region by the plunging breaker and the eroded material was deposited at depths greater than 0.9 foot.

From 12 to 62 hours the foreshore retreated at a faster rate (approximately 0.08 foot per hour). This further widened the inner region as the position of the -0.5-foot contour remained stationary during the first 50 hours. As the material was deposited offshore, the seaward edge of the inshore zone (-0.8-foot depth) moved seaward, creating a flatter outer region of the inshore zone and a steeper offshore slope.

After 40 hours the breaker began to move seaward (with the -0.6-foot contour), and between 62 and 70 hours the breaker type changed from plunging to spilling as the slope in the inshore zone became flatter. After 84 hours the waves broke at a depth of 0.7 foot. From 40 to 94 hours the bar in the inner inshore disappeared as the breaker moved seaward and changed from plunging to spilling.

No apparent lateral variation occurred in the development of the outer edge of the inshore zone; i.e., the movement of the -0.8-foot contour intercept. However, the changes within the inshore zone did vary laterally. Along each profile, as the bar in the inner region disappeared, the shelf in the outer region developed (see Fig. 21). The time when this change occurred varied laterally across the tank, starting first along range 1 and later along range 9.

The inner inshore remained stable from 94 to 160 hours while the beach-fill material was eroded at the average or an above average rate and was deposited in the offshore zone. After 125 hours, more material was deposited on the left side (ranges 5, 7, and 9) than on the right (ranges 1 and 3).

After 160 hours, however, the beach-fill material was eroded at an average or below average rate while the inner inshore along ranges 1 and 3 experienced further erosion. If the experiment had continued past 210

Table 13. Summary of profile development for experiment 70X-10.

Time (hr)	Foreshore	Inner inshore	Outer inshore	Offshore	Breaker conditions			Water temperature (°C)
					Depth (ft)	Type[1]	Angle[2]	
0 to 1	developed characteristic shape	bar formed	no change	deposition between depth of -1.0 and -1.5 ft	0.4 to 0.5	P	C	---------------
1 to 5	no erosion; no change	bar moving shoreward			0.4 to 0.5	P	C	---------------
5 to 12				deposition at -1.0 ft	0.4 to 0.5	P	C	---------------
12 to 14	eroded at rate of 0.08 ft/hr	position of bar stable; elev. varied 0.3 to 0.4 ft		deposition at -0.9 and -1.0 ft	0.4 to 0.5	P	R	---------------
14 to 36			extending seaward	deposition at all depths except -2.0 and -2.1 ft along range -1	0.4 to 0.5	P	R	---------------
36 to 40			erosion at depth of 0.5 ft		0.4 to 0.5	P	R	---------------
40 to 56		erosion of bar started; range -1 at 40 hr, range -1 at 56 hr, and range -9 at 84 hr completed			0.6	P	R	25 to 30
56 to 62			erosion at depth of 0.6 ft		0.6	P	R	27 to 29
62 to 70	SWL retreated still; beach fill began				0.6	P-SP	R	26 to 27
70 to 84	rate of fill = avg.				0.6	SP	R	28 to 30
84 to 94		further erosion			0.7	SP	R	24 to 28
94 to 130		stable	still extending seaward; lateral variation in depth R-1, 0.6 to 0.7 ft; R-9, 0.7 to 0.9 ft		0.7	SP	R	26 to 15
130 to 140	rate of fill >> avg.				0.7	SP	R	14 to 15
140 to 150				deposition at all depths	0.7	SP	R	14 to 15
150 to 160	rate of fill = avg.				0.7	SP	R	12 to 15
160 to 170	rate of fill << avg.	further erosion along ranges -1 and -3			0.7	SP	R	12
170 to 190	rate of fill = avg.				0.7	SP	R	10 to 15
190 to 200	rate of fill = avg.			contours stable for -1.0 to -1.5 ft; ft; deposition below -1.5 ft	0.7	SP	R	7 to 10
200 to 210	rate of fill << avg.				0.7	SP	R	7
200 sand samples mean (mm)	0.29 to 0.68	0.27 to 0.50	0.26 to 0.33	0.25				

[1]P = plunging; SP = spilling.
[2]R = breaks first along range 1; C = breaks uniformly across tank.

hours, further erosion of the inner inshore would possibly have continued across the tank forming the steep slope just below the foreshore, similar to experiment 70X-06. After 160 hours the profiles varied considerably across the tank. Along range 1 the inner region of the inshore was very steep, the shelf at station +8 reached an elevation of -0.5 foot at times, and the offshore region was very steep, with the toe of the offshore at station 23. In contrast, along range 9, the inner region was fairly flat, the shelf elevation at station +8 was only rarely above -0.8 foot, and the offshore zone was flatter, with the toe of the offshore at station 25. The profiles along ranges 3, 5, and 7 varied progressively between these two shapes.

The definite decrease in the median grain size in the seaward direction indicates that material eroded from the upper part of the profile and deposited offshore was generally finer, as would be expected.

c. Comparison of the Two Experiments. The general shape of the profiles and the sequence of events during the development of the profiles appeared to be similar in the two experiments. Also, neither profile reached equilibrium. However, there were differences in the rate of development and the profiles in the wider tank exhibited some significant lateral variations in shape which did not occur in the narrower tank.

(1) Shoreline Recession Rate and Foreshore Shape. The shoreline in experiment 70X-10, after the initial development during the first 12 hours, retreated at an average rate of 0.08 foot per hour for the next 50 hours. In experiment 70X-06, the shoreline retreated at a rate of 0.06 foot per hour for the first 22 hours and then increased to an average rate of 0.14 foot per hour for the next 28 hours. During the period when the shoreline was stabilized by filling backshore, the erosion rate in experiment 70X-06 was 3.53 pounds per hour per foot (5.25 kilograms per hour per meter) of the beach and in experiment 70X-10 was 3.00 pounds per hour per foot (4.46 kilograms per hour per meter) of the beach, or nearly the same. There were no apparent differences in foreshore shape.

(2) Inshore Zone. A bar developed in both tanks almost immediately at station 4 as a result of the plunging breaker and the position of the bar remained fairly stable until the bar disappeared. The erosion of the bar in the inner region created the wide, flat outer region of the inshore. There are two significant differences between the two tanks in this change. In the 6-foot tank this change (from the time the -0.4-foot contour began moving shoreward until the -0.5-foot contour stopped moving shoreward) occurred in about 20 hours with no lateral variation. In the 10-foot tank this change occurred over a 40-hour period, with considerable lateral variation in time of change. The erosion of the bar began and ended sooner along ranges 1, 3, and 5 than along ranges 7 and 9.

The movement of the seawardmost -0.8-foot contour is indicative of the deposition of material offshore and seaward development of the inshore zone. In the 6-foot tank the -0.8-foot contour moved seaward at 22 hours along all three ranges; in the 10-foot tank this change occurred at 16

hours along ranges 1 and 3, at 18 hours along range 5, and at 20 hours along ranges 7 and 9. Near the end of the experiments the -0.8-foot contour was nearly horizontal indicating possible equilibrium in the 6-foot tank and was sloping downward in the 10-foot tank indicating continued deposition at this depth.

After the outer region had developed into a wide, flat shelf after 76 hours in the 6-foot tank and after 94 hours in the 10-foot tank, the depth over the shelf varied laterally. In the 6-foot tank the depth increased from 0.5 to 0.7 foot from range 1 to 5; in the 10-foot tank the depth increased from 0.5 foot along range 1 to 0.9 foot along range 9.

Near the end of each experiment the inner region was further eroded forming a steeper slope just below the foreshore. In the 6-foot tank this erosion (movement of the -0.5-foot contour) occurred after 135 hours and with little lateral variation; in the 10-foot tank this erosion began at 160 hours along range 1 and 170 hours along range 3. Similar erosion may have begun along the other three ranges during the last 5 hours of testing as shown by the movement of the -0.2-foot contour along range 5, the -0.2- and -0.3-foot contours along range 7, and the -0.2-, -0.3-, and -0.4-foot contours along range 9 (see Figs. 13 to 17).

(3) Offshore Zone. No significant difference was observed between the 6- and 10-foot tanks in the way the offshore developed initially, and only minor differences in the rate of deposition. The major difference between the two tanks was the deposition after 100 hours. In the 6-foot tank, material was deposited at depths of 1.0 foot and greater and the shoreward boundary (-0.8-foot contour) of the offshore zone was stationary; in the 10-foot tank, material was still being deposited at depths of 0.8 foot and greater as indicated by the seaward movement of the -0.8-foot contour.

The 6-foot tank had little lateral variation in the offshore zone, but the 10-foot tank had significant lateral variation in rates of deposition offshore and some lateral variation in the slope of this zone. Along range 1 the offshore was very steep and the -2.1-foot contour moved only 1.5 feet in the 210 hours. Along range 9 the slope was not as great and the -2.1-foot contour moved 4 feet (1.22 meters) in the 210 hours.

2. Profile Reflectivity.

The basic profile shapes which evolved during the profile development are shown in Figure 9. Early profiles (broken line in Fig. 9) had a steep foreshore, a short inshore with a longshore bar formed by the plunging breaker, and a gently sloping offshore zone. Later profiles (dashline in Fig. 9) also had a steep foreshore, but the inshore zone widened to a long, flat shelf which terminated in a relatively steep offshore zone.

Chesnutt and Galvin (1974) discussed the processes which reflect wave energy from the movable bed in these experiments. The processes include the conversion of potential energy stored in runup on the foreshore into a seaward-traveling wave, the seaward radiation of energy from a plunging

breaker, and reflection of the incident wave from the movable bed, particularly where the depth over the movable bed changes significantly. Depth changes are significant if the depth difference is an appreciable fraction of the average depth over a horizontal distance less than a wavelength. For conditions of these experiments, the wavelength is 14.3 feet (4.36 meters) in the section seaward of the movable bed, and approximately 9 feet (2.74 meters) over the inshore zone.

a. Reflection from the Foreshore. The foreshore zone developed a relatively stable slope within the first hour of testing, well before the other elements of the movable-bed profile had become prominent. The developed foreshore had an average slope of 0.19 in experiment 70X-06 and 0.20 in experiment 70X-10 which is considerably steeper than the initial 0.10 slope of the movable bed. The initial high values of K_R are probably the result of reflection from the foreshore of waves which dissipated relatively little energy until almost at the foreshore. Reflection from the foreshore is a function of the height of the wave reaching the foreshore, and this height would diminish as the inshore and offshore segments of the profile (Fig. 9) became prominent.

b. Reflection as a Result of Wave Breaking. On the concrete slab the wave broke as a plunging breaker and on the movable-bed profile the wave was initially a less well-developed plunger and evolved to a spilling breaker. The concrete slab had the same slope (0.10) as the initial slope of the movable bed. Because the total reflection was significantly less on the concrete slab (K_R = 0.05) where the plunger is assumed to contribute relatively more to the total reflection, it is likely that reflection from the movable bed by breaking was never very important, and became less important, as the breaker type changed to spilling.

c. Effect of Inshore and Offshore. As the experiment proceeded, the inshore widened and flattened and the offshore steepened. At first, the widening of the inshore dominated; the lowering of the reflection after the high initial values (Figs. 2 and 3) is attributed to the greater energy dissipation in the inshore. The later steepening of the offshore correlates well with the trend toward higher K_R later in the experiments (compare the offshore contour positions in Figs. 11 and 15 with the appropriate reflection curve in Figs. 2 and 3).

With the development of the two reflecting zones (foreshore and offshore) separated by a relatively flat inshore zone, the measured reflected wave was composed of two waves (one from the offshore, the other from the foreshore). A change in phase or amplitude of either reflected wave would change the phase and amplitude of the measured wave. Part of the long-term K_R variability can be attributed to the change in phase difference between these two reflected waves as the foreshore retreated landward and the offshore built seaward.

Chesnutt and Galvin (1974) pointed out an apparent correlation between the movement of the -0.7-foot contour and the variability of the reflection

coefficient, and suggested that the reflection is very sensitive to small changes in the depth near the seaward edge of the inshore zone. These depth changes would cause variability in the reflection of the incident wave from the offshore slope and variability in the amount of energy trapped on the inshore shelf.

The position of the -0.7-foot contour and the reflection coefficient versus time for the two experiments are compared in Figures 38 and 39. The seaward movement of the -0.7-foot contour is an indication of the development of the steep offshore slope. Both figures show the general increase in the reflection coefficient as the -0.7-foot contour moved seaward. In Figure 38 (experiment 70X-06), the same kind of fluctuations (but not as great) in the contour position and reflection coefficient appear as pointed out by Chesnutt and Galvin (1974). The large fluctuations in the reflection coefficient near the end of experiment 70X-10 (Fig. 39) are not matched by large movements in the -0.7-foot contour. However, some lateral variation in the shape of the inshore and offshore zones occurred in the 10-foot tank (Fig. 40) which would cause lateral variations in reflection, and might have confused the reflection measurements in the center of that tank.

IV. DISCUSSION OF RESULTS

1. Wave Height Variability.

Three probable causes of wave height variability in the two experiments are: (a) Wave reflection from the changing profile, (b) re-reflection from the wave generator, and (c) secondary waves. Preliminary experiments had indicated that wave reflection from the movable-bed profile was the major cause of wave height variability and these experiments were conducted primarily to quantify the amount of variability due to reflection.

a. Wave Reflection from the Profile. The K_R varied from 0.08 to 0.20 in experiment 70X-06 and from 0.04 to 0.19 in experiment 70X-10. The K_R values during the development of the foreshore were relatively high, then decreased as the remainder of the profile began to adjust. Later, after the profile had developed a relatively steep offshore slope, the K_R increased and the variation in K_R increased. The variations appear to have been caused by changes in the shape of the second reflecting surface and by the gradual separation of the two reflecting surfaces as the offshore slope prograded seaward (Chesnutt and Galvin, 1974).

b. Re-reflection from the Generator. The reflected wave advanced to the generator and was reflected. As the height of the reflected wave varied, the height of the re-reflected wave varied; as the phase difference between the reflected wave and the generator motion varied with changes in the profile, the height and phase of the re-reflected wave varied. The height of the wave incident to the profile, which was the average of wave heights along the full tank length and was composed of the generated wave and the re-reflected wave, varied from 0.32 to 0.38 foot in experiment 70X-06 and from 0.34 to 0.39 foot in experiment 70X-10. Part of that

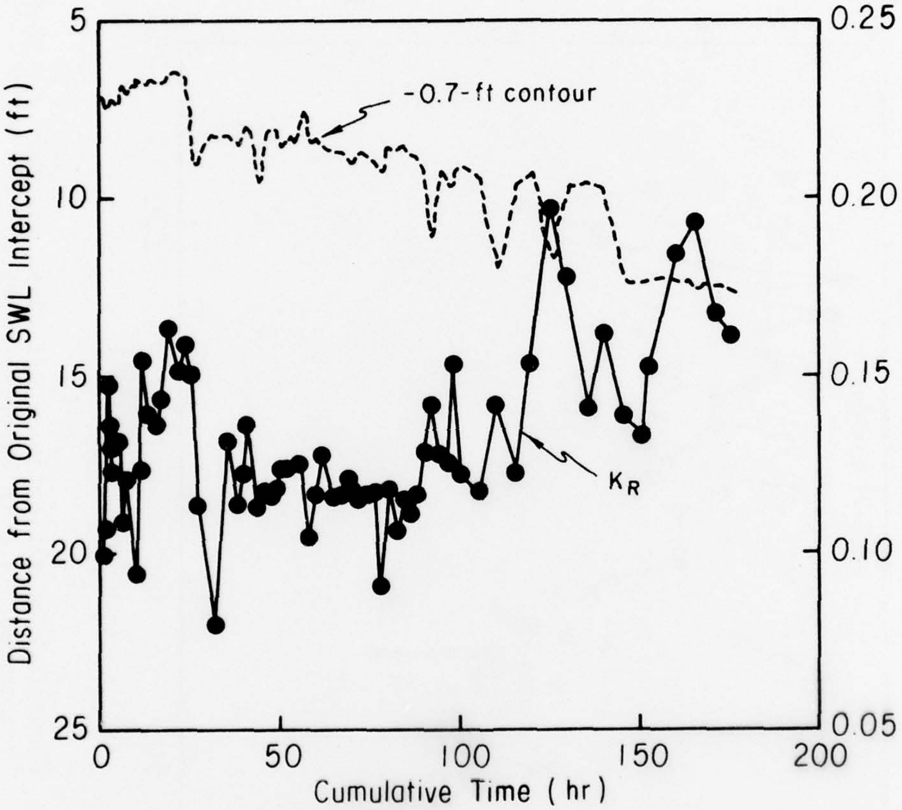

Figure 38. Comparison of reflection coefficient and the -0.7-foot contour position in experiment 70X-06.

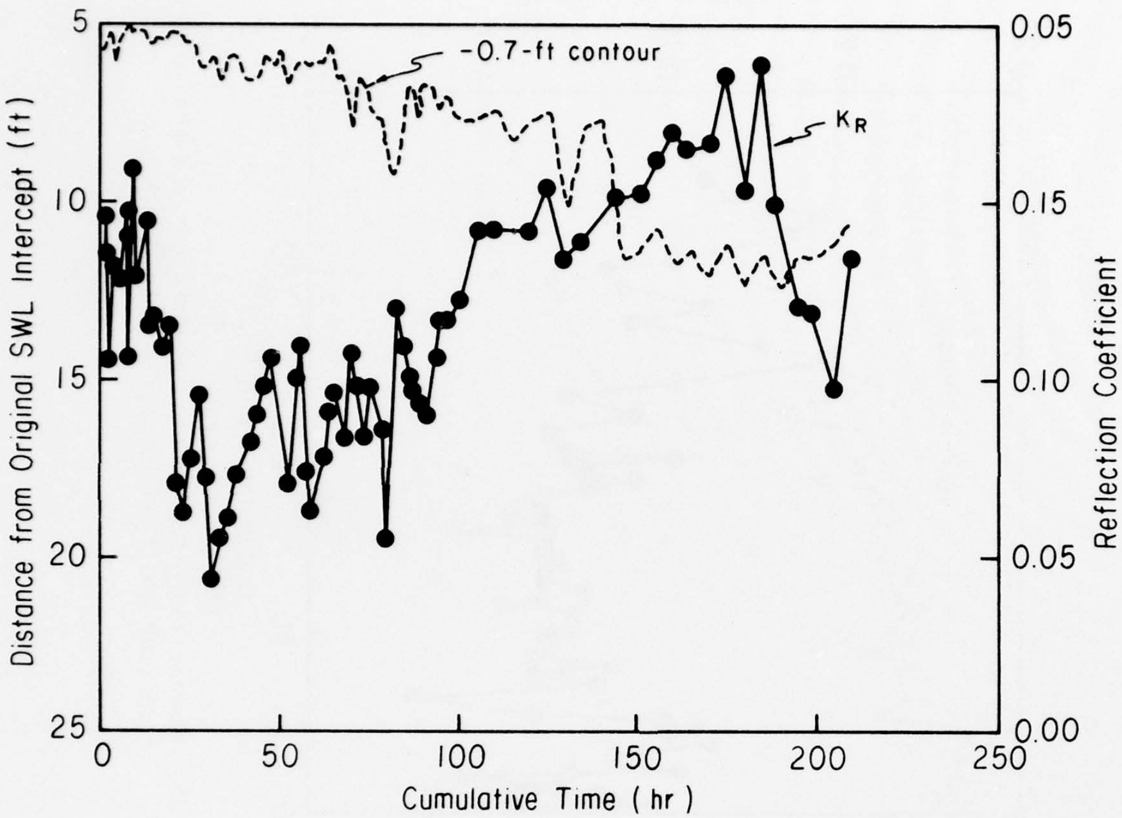

Figure 39. Comparison of reflection coefficient and the -0.7-foot contour position in experiment 70X-10.

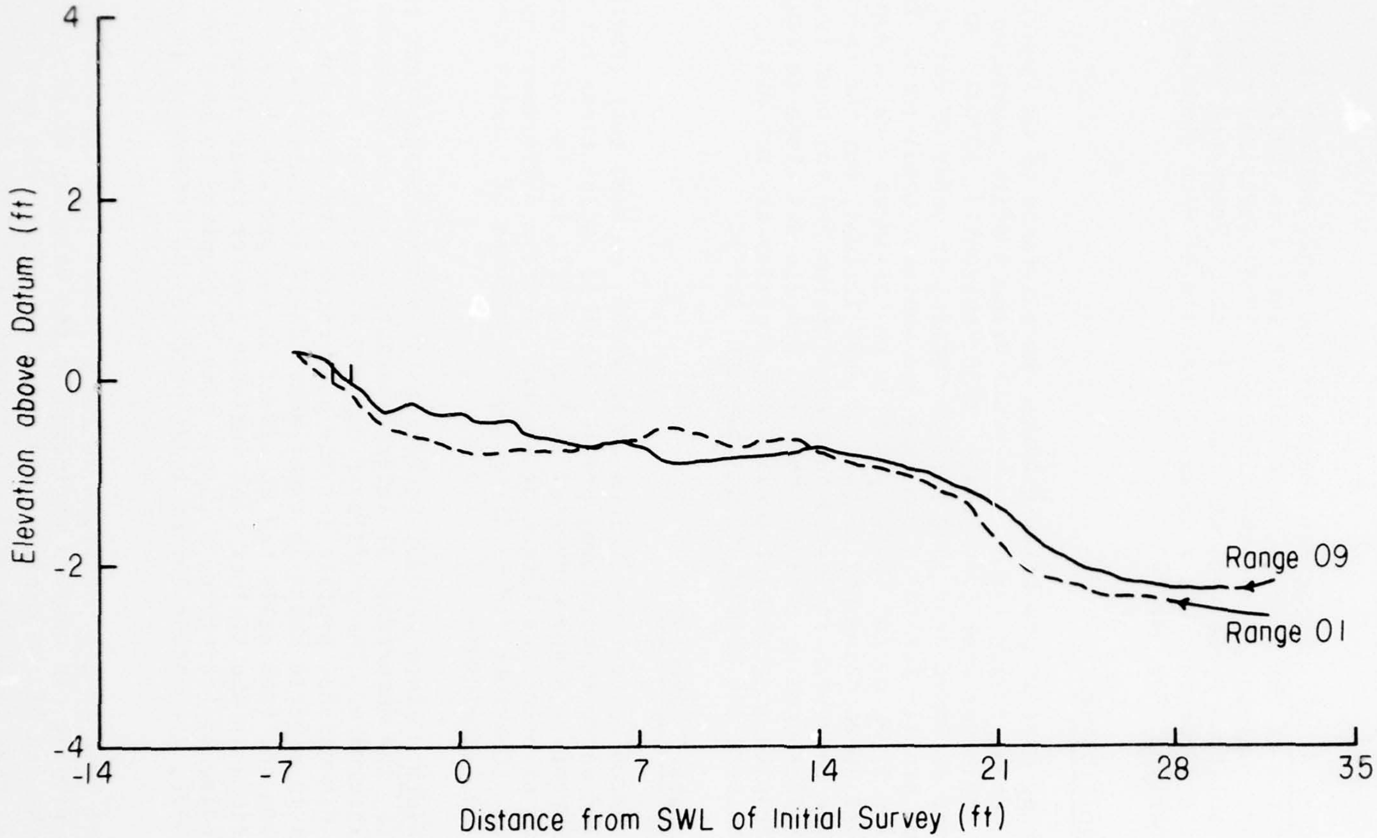

Figure 40. Lateral variation in profile shapes in experiment 70X-10.

variation (0.01 foot or 0.3 centimeter in experiment 70X-06; 0.03 foot or 0.9 centimeter in experiment 70X-10) could be attributed to measurement errors or to variation in the generated wave. The remainder of the variation is likely due to re-reflection.

c. Secondary Waves. Along the length of the tank, between the generator and the toe of the profile, wave heights varied as the result of secondary waves. Galvin (1972) and Hulsbergen (1974) described secondary waves (called solitons by Galvin) and their effects. Secondary waves can be observed on the records, but a detailed analysis of wave shape was not conducted as part of this study.

2. Profile Equilibrium.

In conducting experiments which presume the existence of an "equilibrium" profile, an approximation of that equilibrium profile should be used to start the experiment (see Savage, 1959; Fairchild, 1970a). These experiments were extended over long periods (hours) in hopes of defining the equilibrium profile for the given wave and sediment conditions. The contour position lines or the CONPLT plots in the offshore zone in experiment 70X-06 were approaching horizontal (or equilibrium), but the continued erosion from the backshore indicated that equilibrium had not been reached. Experiment 70X-10 showed no evidence that the profile was close to equilibrium. These results suggest that equilibrium profiles are not easily determined (Chesnutt and Galvin, 1974; Chesnutt, 1975).

3. Other Laboratory Effects.

The differences in test conditions (tank width, initial test length, and uncontrolled water temperature) provide possible explanations for the differences in profile shape discussed in Section III, 1c, but also prevent a rigorous proof of the effect of any one of these differences as definite causes. Chesnutt (1975) discussed the effects of initial test length and water temperature.

a. Tank Width. Since lateral variations in profile shape occur on natural beaches, the occurrence of lateral variations in the two tanks is an expected difference. The profile in experiment 70X-06 can be considered a typical two-dimensional profile for the particular wave conditions, but the variations in profile shape in experiment 70X-10 indicate that the distance between the tank walls had an effect on the profile shape. The lateral variations in the 10-foot tank indicate greater three-dimensional movement of sediment; therefore, a longer time is required to move the sediment offshore, accounting for at least part of the difference in rate of change.

b. Initial Test Length. Changes in the distance from the wave generator to the profile can cause a variation in the velocity field under the waves at the toe of the profile, and therefore affect the rate of profile change in at least two ways. Hulsbergen (1974) has shown that the

relative position of secondary waves to the primary wave causes a variable asymmetry in the velocity field under waves and resulting variation in the shape of the profile and rate of profile change. The critical distance in cases of secondary wave occurrence is the overtake distance, the distance from the generator to the point where the secondary crest of the first wave has been overtaken by the primary crest of the second wave. The overtake length for this wave condition in the 2.33-foot (0.71 meter) water depth was about 26 feet (7.92 meters) and the difference in initial test lengths was 39.3 feet (12.0 meters). Therefore, secondary waves could account for the difference in rate of profile change.

The second way in which the initial test length can be important is in the difference (between the two experiments) of the phase difference between the re-reflected waves and the generated waves. The difference in initial test lengths was 39.3 feet or 2.7 wavelengths. The average incident wave height for the first 20 hours in experiment 70X-06 was 0.35 foot (10.7 centimeters) and in experiment 70X-10 was 0.37 foot (11.3 centimeters). However, the lower incident wave height is associated with the greater initial erosion rate. Thus, it is not apparent how the re-reflection affected the beach.

c. Water Temperature. The water temperature varied from 30° to 7° Celsius for the experiments which began in May and August and continued into early December. The dynamic viscosity varied from 1.7×10^{-5} to 3.0×10^{-5} pounds-second per square foot (0.798×10^{-2} to 1.430×10^{-2} grams-second per square centimeter) (Daily and Harleman, 1966). Quantification of temperature effects is not possible here because of the unquantified effects of the different tank dimensions and the lack of temperature data for the first 40 hours of experiment 70X-10. However, two points can be made. At 22 hours in experiment 70X-06, the water temperature dropped from 28° to 18° Celsius and the rate of shoreline recession increased from 0.06 to 0.14 foot per hour (Fig. 37). This supports the hypothesis that colder, more viscous water increases the sediment transport capacity of waves (Fairchild, 1959). The gradual increase in viscosity may have prevented the profile from reaching equilibrium by continuing to increase the sediment-carrying capacity of the water.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions.

(a) In two experiments with a water depth of 2.33 feet, a wave period of 1.90 seconds, and a generator stroke of 0.39 foot, the nominal incident wave height was 0.36 foot. Reflection measurements in the control tanks with a fixed-bed profile varied from 0.03 to 0.07, indicating that the wave generators were operating uniformly and that the measurement error in determining the reflection coefficient, K_R, was ±0.02 (Table 6).

(b) K_R varied from 0.08 to 0.20 in experiment 70X-06 and from 0.04 to 0.19 in experiment 70X-10. The variation in K_R correlates with profile changes. K_R more than doubled in the first few minutes of wave

action on the movable bed due to development of the steeper foreshore. The reflection decreased as the inshore widened. Later increases in K_R occurred when the offshore steepened (Figs. 2, 3, 38, and 39).

(c) Profiles in the two experiments developed in the same sequence, but did not reach equilibrium (Figs. 10 to 17).

(d) Within the first hour of testing the foreshore developed a shape which was in dynamic equilibrium. During the time before the shoreline stabilization, the position of the foreshore retreated at average rates which varied from 0.06 to 0.14 foot per hour (Figs. 10 to 19; Table 8).

(e) Changes in the sediment-size distribution along the profile appear to be measurable, even in the laboratory with the use of fine sand (Table 11).

(f) Lateral variations in the development and the shape of the inshore zone in the 10-foot tank did not occur in the narrower tank, indicating that the tank width may have affected the profile development (Figs. 10 to 17 and 40).

(g) Differences in the rate of shoreline erosion and profile development may have been caused by the difference in initial test length, which affects secondary waves and re-reflection from the wave generator (Fig. 21).

(h) The increase in the rate of shoreline recession at 22 hours in experiment 70X-06 occurred coincidentally with a 10°-Celsius drop in water temperature. This supports the hypothesis that colder, more viscous water will transport more sediment (Fig. 37).

2. Recommendations.

(a) Because of varying reflectivity of the profiles, incident wave measurements to characterize a three-dimensional coastal engineering experiment should be based on calibration of the wave generator rather than isolated wave measurements during the experiment.

(b) Experimenters should be cautious in defining equilibrium profile conditions.

(c) When conducting movable-bed experiments, water temperature should be kept near constant.

LITERATURE CITED

ALLEN, R.H., "A Glossary of Coastal Engineering Terms," MP 2-72, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington, D.C., Apr. 1972.

CHESNUTT, C.B., "Laboratory Effects in Coastal Movable-Bed Models," *Proceedings of the Symposium on Modeling Techniques*, 1975, pp. 945-961.

CHESNUTT, C.B., "Reduced Data from the Laboratory Effects in Beach Studies (LEBS) Experiments 70X-06 and 70X-10," Laboratory Memorandum No. 1, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., unpublished, 12 August 1977.

CHESNUTT, C.B., and GALVIN, C.J., "Lab Profile and Reflection Changes for $H_o/L_o = 0.02$," *Proceedings of the 14th Conference on Coastal Engineering*, 1974, pp. 958-977.

CHESNUTT, C.B., et al., "Beach Profile Development on an Initial 1:10 Slope of 0.2 mm Sand," *Transactions of the American Geophysical Union*, Vol. 53, Apr. 1972, p. 411.

DAILY, J.W., and HARLEMAN, D.R.F., *Fluid Dynamics*, Addison Wesley, Reading, Mass., 1966, p. 33.

FAIRCHILD, J.C., "Suspended Sediment Sampling in Laboratory Wave Action," TM-115, U.S. Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., June 1959.

FAIRCHILD, J.C., "Laboratory Tests of Longshore Transport," *Proceedings of the 12th Conference on Coastal Engineering*, 1970a, pp. 867-889.

FAIRCHILD, J.C., "Wave Diffraction in a Laboratory Movable-Bed Setup," Bulletin and Summary of Research Progress Fiscal Years 1967-69, Vol. III, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Washington, D.C., 1970b, pp. 29-40.

GALVIN, C.J., and STAFFORD, R.P., "Wave Height Variability on Laboratory Beaches," *Transactions of the American Geophysical Union*, Apr. 1970, p. 322.

GALVIN, C.J., "Finite-Amplitude, Shallow Water-Waves of Periodically Recurring Form" *Proceedings of the Symposium on Long Waves*, 1972, pp. 1-32.

HULSBERGEN, C.H., "Origin, Effect, and Suppression of Secondary Waves," *Proceedings of the 14th Conference on Coastal Engineering*, 1974, pp. 392-411.

SAVAGE, R.P., "Laboratory Study of the Effect of Groins on the Rate of Littoral Transport: Equipment Development and Initial Tests," TM-114, U.S. Army, Corps of Engineers, Beach Erosion Board, Washington, D.C., June 1959, p. 56.

SAVAGE, R.P., "Laboratory Determination of Littoral-Transport Rates," *Journal of the Waterways and Harbors Division*, Vol. 88, No. WW2, May 1962, pp. 69-92.

STAFFORD, R.P., and CHESNUTT, C.B., "Procedures Used in 10 Movable-Bed Experiments," Vol. I, MR 77-7, *Laboratory Effects in Beach Studies*, U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Va., June 1977.

U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, *Shore Protection Manual*, Vols. I, II, and III, 2d ed., Stock No. 008-022-00077-1, U.S. Government Printing Office, Washington, D.C., 1975, 1,160 pp.

APPENDIX

EXPERIMENTAL PROCEDURES FOR 70X-06 AND 70X-10

This appendix documents those aspects of the experimental procedures which were unique to experiments 70X-06 and 70X-10. The procedures common to all experiments are documented in Volume I (Stafford and Chesnutt, (1977).

1. Data Collection.

a. Regular Data.

(1) Wave Height Variability. Except for the initial 10-minute run of each experiment, two wave envelopes during each run were recorded with wave gages moving along the center of each tank between stations +15 and +90 in experiment 70X-06 and +15 and +55 in experiment 70X-10 with the instrument carriage moving at a near-constant speed of 10 feet per minute. Wave records 002 through 006 from experiment 70X-06 contain only the envelopes from station +15 to +90, because the runs were too short to permit recording of two envelopes.

(2) Beach Nourishment. These two experiments were unique in that after 54 hours in the 6-foot tank and 62 hours in the 10-foot tank, the beach had eroded to the back of the tank. From then until the end of each experiment, sand was periodically added to the backshore to maintain an adequate supply. The following procedure was used throughout experiment 70X-06 and after 125 hours in experiment 70X-10, to determine the weight and volume of sand added. (Between 62 and 125 hours in experiment 70X-10, only the weight of the sand was determined.)

(a) A 1-pound coffee can, in good condition, with a known weight, diameter, and height was used.

(b) The can was filled, tapped in a "standard manner", and the top leveled.

(c) The weight of the full can was recorded to the nearest ounce.

(d) The sand was dumped into a larger bucket for temporary stockpile until the backshore was rebuilt.

From 54 to 92 hours in experiment 70X-06 and from 62 to 100 hours in experiment 70X-10, the sand was added only between runs and the backshore was rebuilt to provide a uniform fill 0.5 foot wide with a vertical face across the width of the tanks with a top elevation of 0.67 foot. After 92 hours in experiment 70X-06 and 100 hours in experiment 70X-10, sand was added to the backshore as needed during the runs, in addition to rebuilding the 0.5-foot-wide fill between runs.

Determining the weight and volume of the filled cans of sand does not provide actual weight or actual volume. Without measurements of the moisture content [bulk densities probably ranged from 114 to 125 pounds per

cubic foot (personal communication, G.W. Callendar, CERC, 4 May 1977)], the data on sand addition are of no quantitative value. However, the weight when calculated for 10-hour intervals and compared with the average for the experiments provides qualitative information on periods of significantly greater or lesser erosion.

(3) Breakers. The primary source of breaker data was the study of the 35-millimeter slides. Table 3 shows the times during runs when slides were taken of breakers. After 100 hours in experiment 70X-10 and 115 hours in experiment 70X-06, the practice of taking a slide of the breaker just before the end of the run was discontinued. Knowing the station of landmarks on the tank wall, the slides provided sufficient data to determine the position and type of breakers throughout the two experiments.

(4) Water Temperature. After 38 hours in experiment 70X-10 and throughout experiment 70X-06, water samples were collected at the bottom and at the water surface near the toe of the profile in the early morning and late afternoon of each test day.

b. Special Data. Three types of special data were collected, and Table 2 indicates the times at which each type was collected.

(1) Profile Surveys. After 100 hours in both tests, profiles were surveyed along ranges 0.5 foot apart at 0.5-foot intervals from station -6.5 to +12.0. At 200 hours in the 10-foot tank, and at 150 and 175 hours in the 6-foot tank, the seaward limit of the survey was extended to 19 feet. These seaward distances were chosen to provide dense surveys over the most active part of the profile.

(2) Sand Samples. In experiment 70X-10, sand samples were collected at 200 hours, 10 hours before the termination, along profiles at ranges 1, 3, 5, 7, and 9 at 1-foot intervals from station -6 to 0, at 5-foot intervals from station 0 to +25, and at other prominent features along each profile. In experiment 70X-06, sand samples were collected at 150 hours, near the end of the experiment, along profiles at ranges 1, 3, and 5 at intervals which varied from 2 to 3 feet from station -6 to +26.

2. Data Reduction.

a. Wave Height Variability. All wave height data collected in these two experiments were reduced by the manual method. Twenty percent of the wave records were also reduced by the automated method.

b. Sediment-Size Distribution Data. All samples were analyzed in the CERC Petrology Laboratory using the RSA. Approximately 5 percent of the samples were also analyzed by project personnel using the dry sieve method as a quality control measure.

c. Breaker Data. Breaker type and position were determined from the slides. Using known positions on the tank walls as references, the station of the breaking point was estimated. Breaker position versus time

was plotted, superposed on the contour movement plots and the breaker depth was then determined. Comparison of the contour and breaker position movement plots from these two experiments with similar plots from experiments 71X-06 and 71X-10 where the breaker position was determined and recorded during each run, indicates that the estimates from the slides were probably within 1 foot of the actual position.

Chesnutt, Charles B.
Laboratory effects in beach studies. Volume II. Movable-bed experiments with H_o/L_o = 0.021 (1970) / by Charles B. Chesnutt and Robert P. Stafford. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
89 p. : ill. (Miscellaneous report - U.S. Coastal Engineering Research Center ; 77-7)
Two movable-bed experiments were conducted in 6- and 10-foot-wide wave tanks with waves directed normal to the initial shoreline for 175 and 210 hours. Reflection coefficient variations were significant and were related to wave-induced changes in the profile shape. Lateral variations in the rate of profile development occurred in the 10-foot tank, but not in the 6-foot tank.
1. Coastal engineering. 2. Breakers. 3. Currents. 4. Movable beds. 5. Wave generators. 6. Wave reflection. 7. Wave tanks. I. Title. II. Stafford, Robert P., joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 77-7.

TC203 .U581mr No. 77-7 627

Chesnutt, Charles B.
Laboratory effects in beach studies. Volume II. Movable-bed experiments with H_o/L_o = 0.021 (1970) / by Charles B. Chesnutt and Robert P. Stafford. – Fort Belvoir, Va. : U.S. Coastal Engineering Research Center ; Springfield, Va. : available from National Technical Information Service, 1977.
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TC203 .U581mr No. 77-7 627

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TC203 .U581mr No. 77-7 627